The Republic of the Union of Myanmar

The Study
on
Proposal for Improvement of Electricity Supply
in
Thilawa Area
in
Myanmar

Final Report

January 2018

Japan International Cooperation Agency (JICA)

Nippon Koei Co., Ltd.

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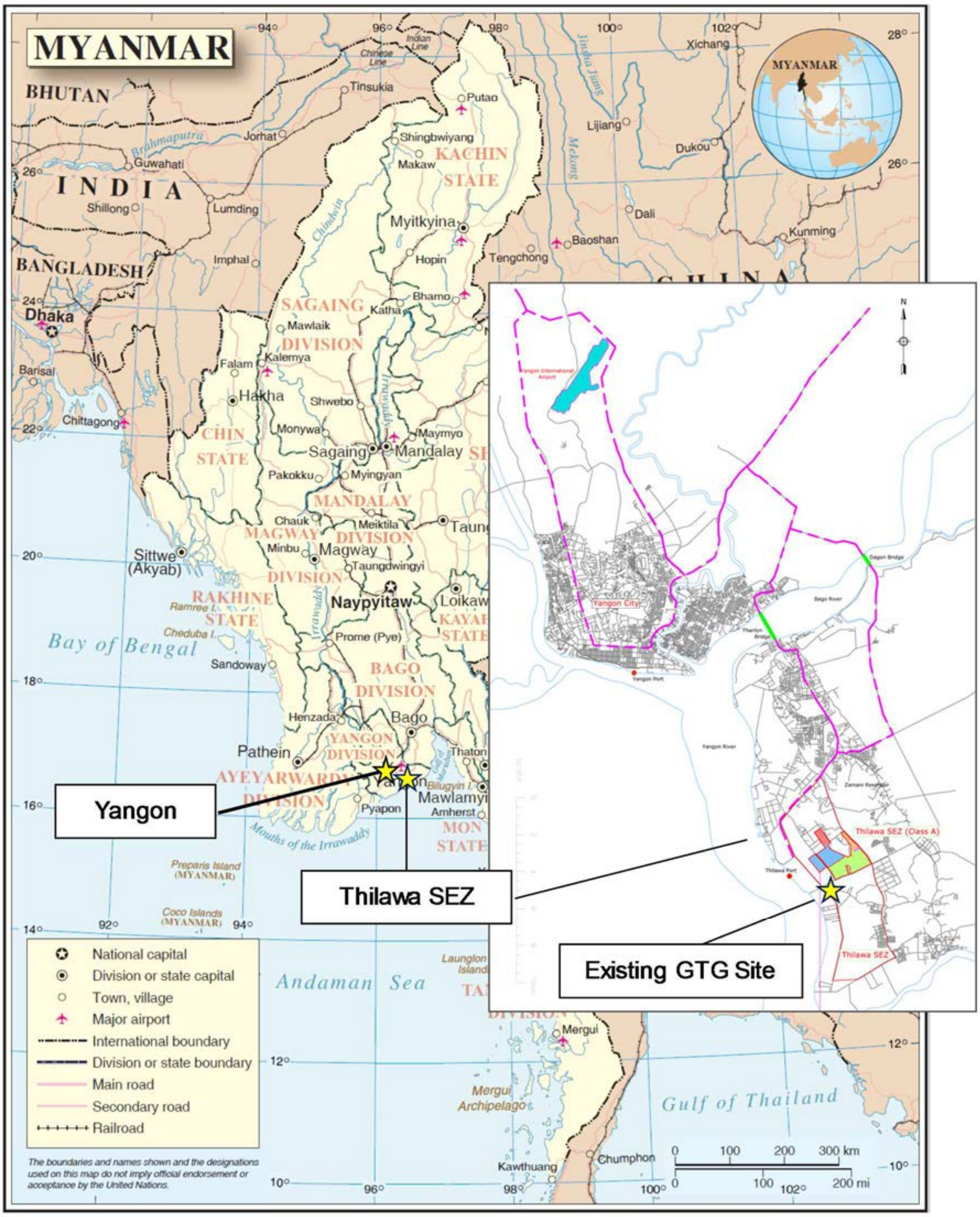
Location Map of this Project



Source: Prepared by the JICA Study Team based on UN map

Location Map of this Project

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Abbreviations and Exchange Rate

Abbreviations

Abbreviations	English
ADB	Asian Development Bank
BBTUD	Billion British Thermal Unit per day
BTU	British thermal unit
CAPEX	Capital Expenditure
COD	Commercial Operation Date
DEPP	Department of Electric Power Planning
DSEZ	Dawei Special Economic Zone
DPTSC	Department of Electric Power Transmission and System Control
ECD	Environmental Conservation Department
EDC	Electricity Development Committee Energy Development Committee
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMC	Energy Management Committee
EPD	Energy Planning Department
EPGE	Electric Power Generation Enterprise
ESE	Electricity Supply Enterprise
FIL	Foreign Investment Law
FIRR	Financial Internal Rate of Return
FS	Feasibility Study
FSL	Full Supply Level
FSRU	Floating Storage and Regasification Unit
FSU	Floating Storage Unit
GCV	Gross Calorific Value (High Heating Value)
GCC	Generation Control Center
GDP	Gross Domestic Product
GEG	Gas Engine Generator
GTCC	Gas Turbine Combined Cycle
GTG	Gas Turbine Generator
HPGE	Hydropower Generation Enterprise
HRD	Human Resources Development
HRSG	Heat Recovery Steam Generator
IEA	International Energy Agency
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IPP	Independent Power Producer
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JOGMEC	Japan Oil, Gas and Metals National Corporation

Abbreviations	English
LNG	Liquefied Natural Gas
MEPE	Myanmar Electric Power Enterprise
MIC	Myanmar Investment Committee
MIL	Myanmar Investment Law
MJ/Nm^3	Mega Joule per Normal cubic meter
MJTD	Myanmar Japan Thilawa Development Limited
mmBtu	Million British thermal unit
mmscfd	Million standard cubic feet
MP	Master Plan
MOA	Memorandum of Agreement
MOEE	Ministry of Electricity and Energy
MOPF	Ministry of Planning and Finance
MOGE	Myanmar Oil and Gas Enterprise
MONREC	Ministry of Natural Resources and Environmental Conservation
MOU	Memorandum of Understanding
MPE	Myanmar Petrochemical Enterprise
MPPE	Myanmar Petroleum Products Enterprise
NCV	Net Calorific Value (LHV)
NECCCC	National Environmental Conservation and Climate Change Committee
NEDO	New Energy and Industrial Technology Development Organization
NEMC	National Energy Management Committee
NGO	Non Governmental Organization
NLD	National League of Democracy
Nm^3	Normal Cubic Meter
NPV	Net Present Value
ODA	Official Development Assistance
OPEX	Operating Expense
PM	Particle Matter
PPA	Power Purchase Agreement
SCF	Standard Cubic Feet
SEA	Strategic Environmental Assessment
SPC	Special Purpose Company
SPDC	State Peace and Development Council
SRV	Shuttle Regasification Vessel
TSMC (TSEZMC)	Thilawa SEZ Management Committee
WB	World Bank
YCDC	Yangon City Development Committee
YESB	Yangon City Electricity Supply Board
YESC	Yangon Electricity Supply Corporation

Exchange Rate

Exchange rate (as of January 23, 2018, Central Bank of Myanmar):

- MMK (Kyats) 1,342.0 = USD1.00
- MMK (Kyats) 1,209.9 = JPY 100
- USD 1.00 = JPY 110.92 (Based on the exchange rates for MMK-USD and MMK-JPY)

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Executive Summary

Chapter 1 General Background

In this Chapter, 1) Economic and financial situation, and 2) Overview of power sector in Myanmar are described.

Major power sources in Myanmar are hydro (approx. 60%) and gas (approx. 40%). Previously, more than 70% of power was supplied by hydro; however, the percentage was slowly decreasing due to installation of new gas power plant to meet increasing demand. The share of hydropower is 58.6% in 2016.

The power generation in Myanmar is increasing with 13% growth rate, to catch up with the growth in electricity demand. The annual power generation in fiscal year 2010-11 was 8,598.1 GWh and the one in fiscal year 2015-16 was 15,864.8 GWh.

Chapter 2 Survey Policy

In this Chapter, 1) Background and purpose of the survey, 2) Current situation of the sector and area, 3) Issues on the study, 4) Policy on the study, and 5) Methodology for implementation of survey are described.

Following three issues were to be studied.

- Issue-1: Transmission/Distribution Line and Substation Facilities nearby Thilawa SEZ
- Issue-2: Gap between Power Demand and Supply in Yangon
- Issue-3: Water Supply for the Installation of Add-on of HRSG and ST

For the issues, three survey policy was set.

- Policy-1: Study on the Existing National Grid, Identification of the Problem, and Plan for Countermeasures
- Policy-2: Confirmation on the Progress of the Master Plan and Study for Supporting Plan
- Policy-3: Water Resource and Study on its Utilization and Reduction of Water Use

The study was conducted in three stages as shown below:

- <First Stage> Confirmation of Current Situation and Identification of Problems
- <Second Stage> Conceptual Design
- <Third Stage> Preparation of Final Report and Discussion

Chapter 3 Project Plan and Technical Feasibility

In this Chapter, project plan and its technical feasibility was examined.

3.1 Study Items for the Project Implementation

The following options are compared and evaluated in terms of 1) technical, 2) financial and economic, and 3) environmental and social aspects:

Table ES3.1-1 Options for Comparison

	Option 1	Option 2	Option 3	Option 4
Characteristics	Combined cycle of the existing 2 GTs	Relocate and rehabilitate 1 GT and 1 ST from Ywama	1. Relocate and rehabilitate GT from Ywama 2. Combined cycle of 3 GTs	Option 1 + Option 2
Composition of Plant (GT:G:STG)	2:2:1	2:2 (Existing) 1:1:1	3:3:1	2:2:1 1:1:1:
Additional Capacity (MW)	25(ST)	23.2(GT)+9.0(ST)	23.2(GT)+36.6(ST)	25(ST) +23.2(GT)+9.0(ST)
Total Capacity (MW)	75 (50+25)	82.2 (50+32.2)	109.8 (50+59.8)	107.2 (50+57.2)
Estimated water consumption (ton/hour)	250 (ACC) 3,340 (WCC)	83 (ACC) 1,104 (WCC)	375 (ACC) 5,010 (WCC)	333 (ACC) 4,444 (WCC)
EPC cost (Million USD)	*This amount is not published at this public edition of the report.*	*This amount is not published at this public edition of the report.*	Less than Option 4	*This amount is not published at this public edition of the report.*
Environment (air)	Emission gas from existing 2 GTs can comply with target level.	It is necessary to check whether the rehabilitation of 1 GT and ST from Ywama can comply with the target level for emission or not.	Same as the left information	Same as the left information
Environment (water use and ground subsidence)	Difficult to take groundwater due to shortage of groundwater resource and avoidance of ground subsidence. Necessary to take surface water.	Same as the left information	Same as the left information	Same as the left information
Social	No resettlement, acquisition, and income restoration	No resettlement, acquisition, and income restoration	No resettlement, acquisition. Income restoration may be required (but only one or two households).	No resettlement, acquisition. Income restoration may be required (but only one or two households).
Construction period	24-30 months	19 months	(36 months)	30 months

Source: JICA Study Team

3.2 Machinery Facility Plan and Equipment Modification Work

In this Section, machinery facility plan and equipment modification work are proposed based on the site investigation for 1) Thilawa Add-on Combined Cycle and 2) Ywama Relocation Combined Cycle.

3.3 Power Transmission System

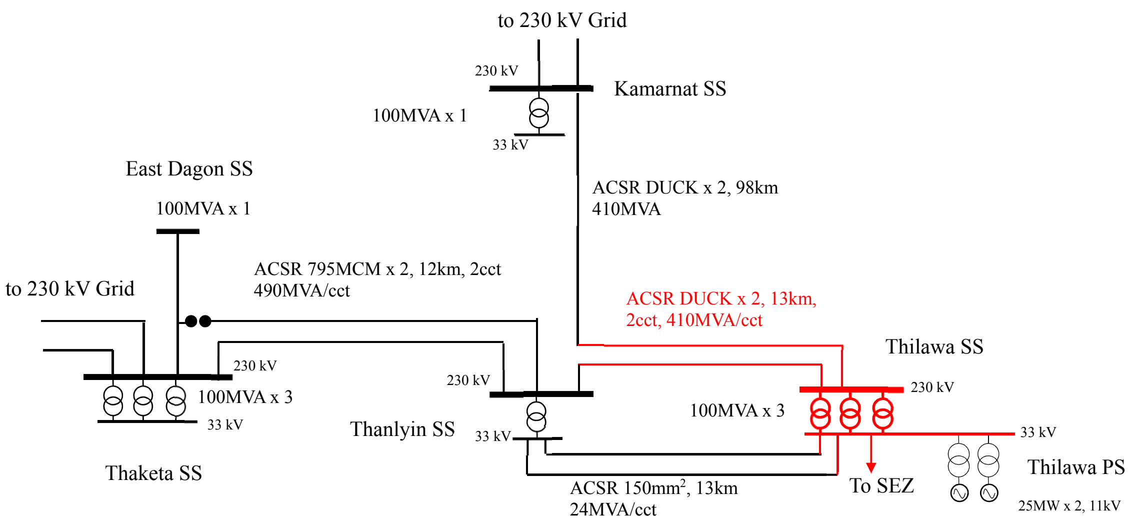
Myanmar has rich water power resources but most of them are generally concentrated in the central and northern regions. The load center of Yangon City is receiving hydropower from the central and northern regions through 230 kV transmission lines. Not only receiving power from the northern regions, Yangon

City is also self-supporting its power demand through four major thermal power plants, namely: Hlawga Power Station, Thaketa Power Station, Ywama Power Station, and Ahlone Power Station, which are located in the city center.

The Thilawa Special Economic Zone (SEZ) is now receiving power from the Thilawa Power Station, which has two gas turbine generators of 25 MW, and from the Thanlyin Substation, which is 13 km from the MJTD office, through two routes of 33 kV single circuit distribution lines. Each 33 kV distribution line has the 150 mm^2 ACSR conductor, which has a maximum power transmission capacity of 24 MVA.

The new 230/33 kV Thilawa Substation, which is located next to the Thilawa Power Station, and the 230 kV transmission line, connecting the substation to the national 230 kV power grid, are now under construction to meet the increasing demand of the SEZ.

The new 230/33 kV Thilawa Substation, and 230 kV 2cct transmission line are under-constructing, therefore The Thilawa power station and SEZ will be connected to Thanlyin and Kamarnat Substations which is connected to the 230 kV national power network of Myanmar, as shown in Figure ES3.3-1.



Prepared by JICA Study Team

Figure ES3.3-1 Power System for Sending Power to Thilawa SEZ after Completion of Thilawa Substation in 2017

When Thilawa Power Station is repowered, following three (3) additional generators shall be connected to the independent 33 kV bus bar system, to avoid increase of short-circuit current of the existing 33 kV bus system.

- Generator (23.2 MW) for gas turbine from Ywama P/S
- Generator (9 MW) for steam turbine from Ywama P/S
- Generator (25 MW) for steam turbine to be added to the existing two (2) gas turbines of Thilawa P/S

3.4 Evaluation of project's affection to the power system

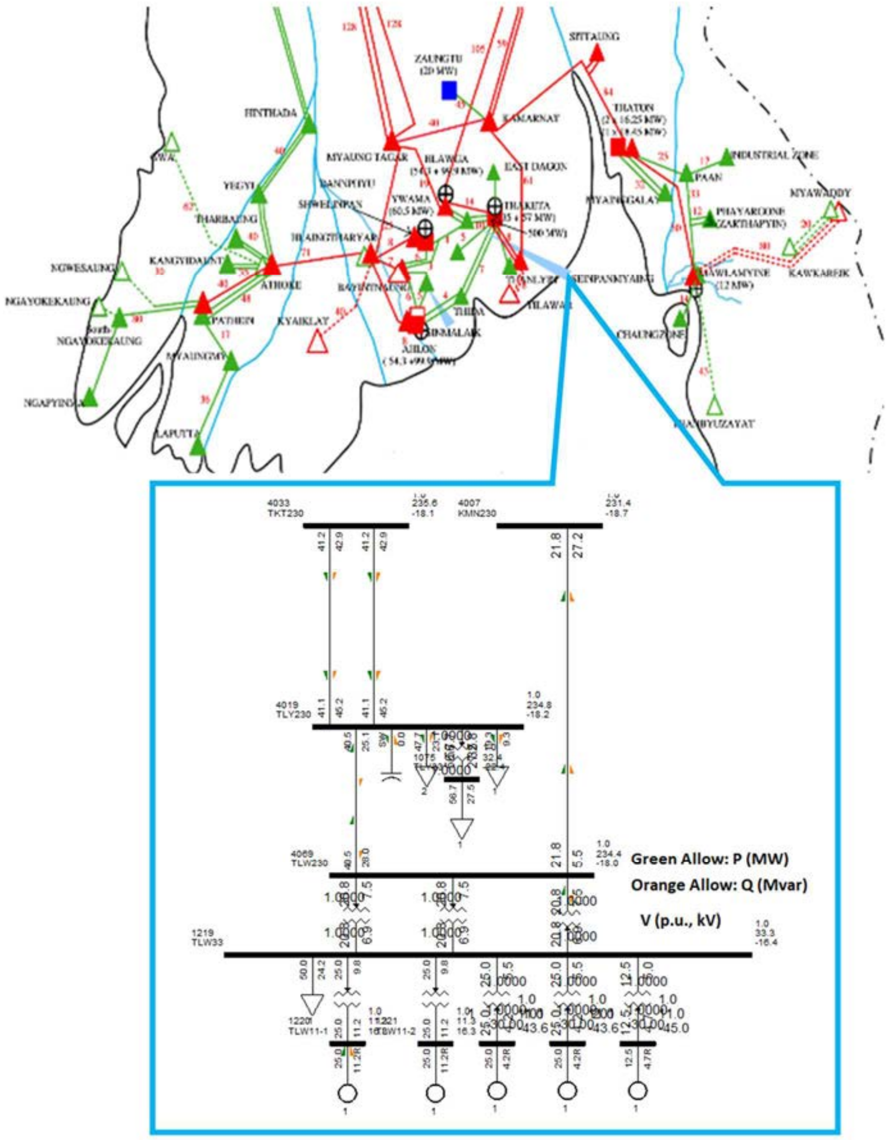
The affection to the vicinity power system related to the project should be evaluated based on the power system analysis utilizing PSSE software.

The evaluation method of the project's affection on the power system was conducted on the local power system including Thilawa Power Station and Yangon area from the following main aspects. System stability analysis is performed based on data and information provided by DPTSC.

(1) System Review from the local power system related to the project

According to the Power Development Plan in the local power system, Thilawa S/S will be connected to Thaketa S/S though Thanlyin S/S with 230 kV transmission line.

The planned single line diagram of Thilawa Power Station after repowering and the local power system is shown in Figure ES3.4-1.



Source: JICA Study Team based on the map provided by DPTSC

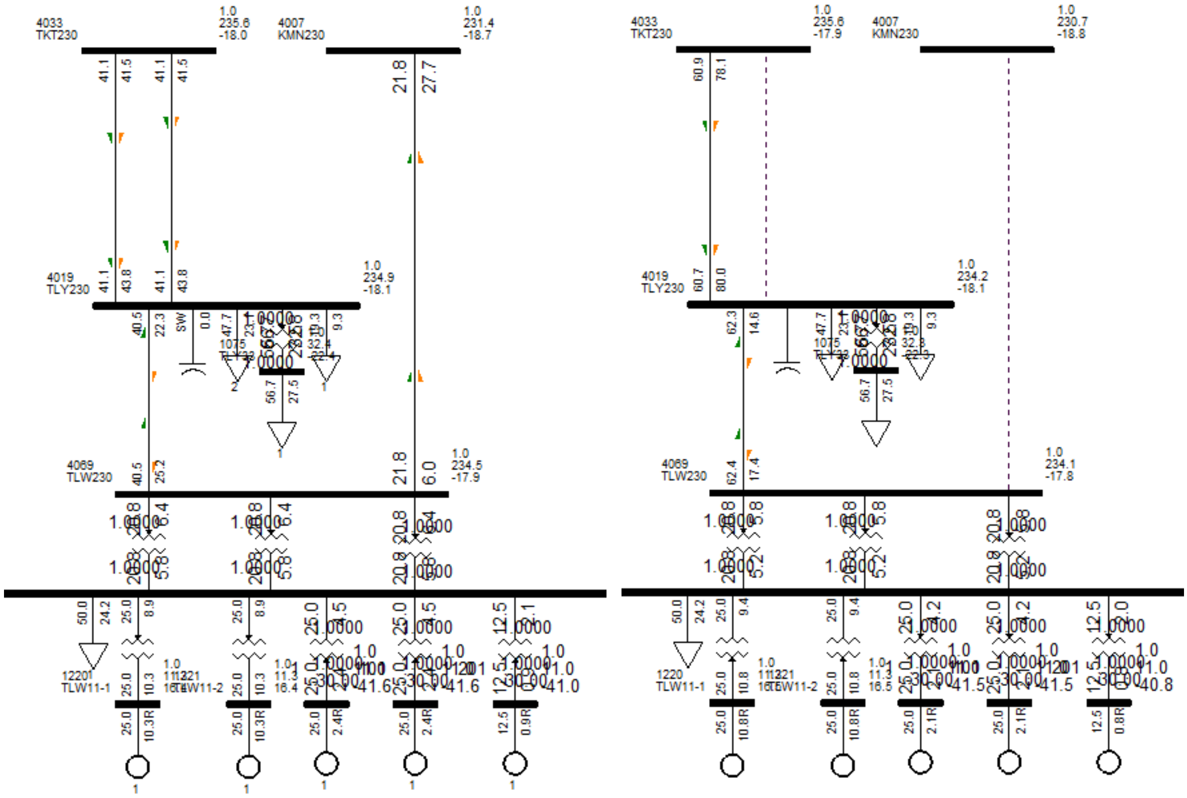
Figure ES3.4-1 System configuration for Evaluation

(2) Evaluation of power flow aspect

From the power flow analysis, the following result was ensured after repowering of Thilawa P/S and related reinforcement of Transmission etc. as shown in Figure ES3.4-2.

Based on the result of the power system analysis study, necessary equipment such as shunt reactor or condenser will not be required to be installed in substations belong the local power system related to Thilawa Power Station for keeping each level voltage within restricted band level.

[Normal Conditions] [Disturbance Condition]



Source: JICA Study Team

Figure ES3.4-2 Simulation Result of Power Flow under Normal Conditions and Disturbance Situations

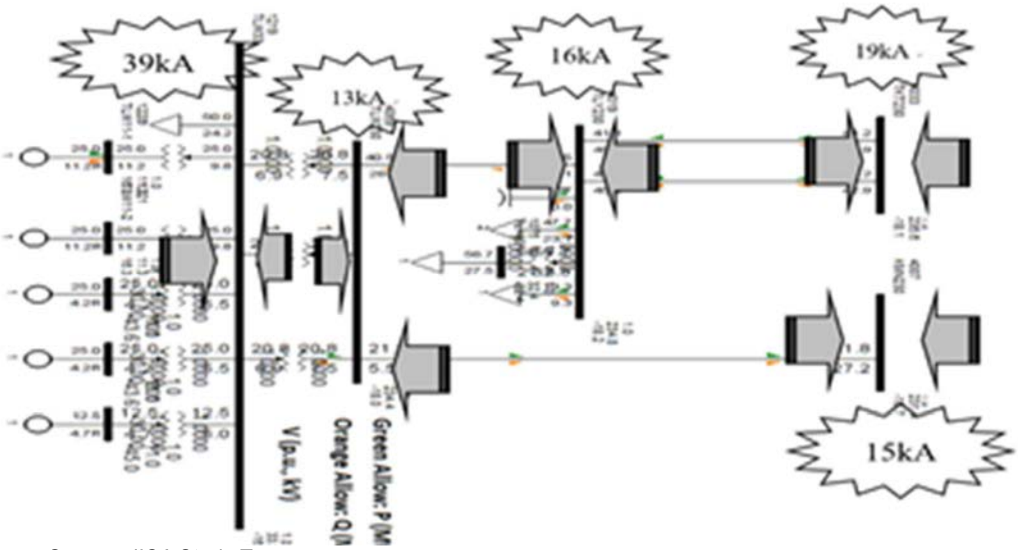
(3) Evaluation of Short Circuit Capacity

Judging from the result of simulation with taking severe case into consideration, there seems to be no severe problem after repowering of Thilawa P/S because total short circuit value of 33 kV bus is under 40kA which is within tolerable capacity for related 33 kV circuit breaker

However, the circuit breaker level of 33 kV system seems to be very high approaching the maximum short circuit level. So, it is recommended to check again by using exact impedance such as internal impedance of generators and step-up Transformer etc. and to utilize high impedance step-up transformer for additional generators or change the connection of generators in Thilawa P/S if required.

Several convection cases of generates were evaluated to reduce the short circuit level of the 33 kV bus instead of adaption of adaption of high impedance step-up transformer because of less cost of install and O&M as mentioned hereafter.

On the other hand, regarding to the 230 kV bus, there might be no problem as shown in Figure ES3.4-3



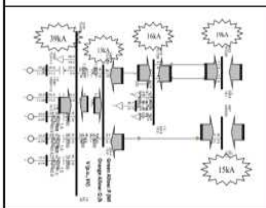
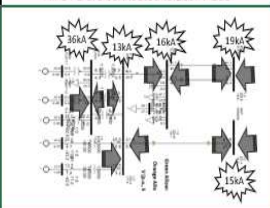
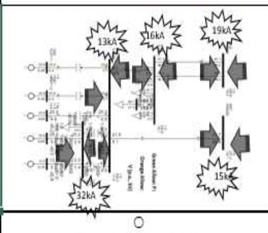
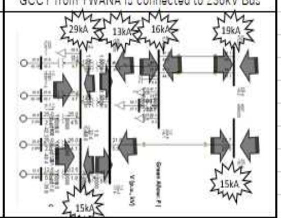
Source: JICA Study Team

Figure ES3.4-3 Short Circuit Value of 33 kV and 230 kV Bus

(4) Tentative Connection Options of Generators in Thilawa P/S

For reducing the short circuit level of 33 kV Bus in Thilawa P/S of Option 1 as mentioned above, several combinations of connection options of generators in Thilawa P/S were carried out and made comparison among connection combinations as shown in Table ES3.4-1.

Table ES3.4-1 Comparison of Connection Options of Generators in Thilawa P/S

Option NO		Option 1	Option 2	Option 3	Option 4
Configulation		All Generators are connected to 33kV Bus	All GTG are connected to 33kV Bus All STG are connected to 230kV Bus	Thilawa GCCT is connected to 230kV Bus GCCT from YWANA is connected to 33kV Bus	Thilawa GCCT is connected to 33kV Bus GCCT from YWANA is connected to 230kV Bus
					
Short Circuit Aspect	Evaluation (Max Current)	▲ (39kA at THILAWA 33kV Bus)	○ (36kA at THILAWA 33kV Bus)	○ (32kA at THILAWA 33kV Bus)	◎ (29kA at THILAWA 33kV Bus)
	Countermeasure	· Adaptopn of High Inpedance to Step-Up Tr of G · Sries Reactol between 33kV Buses or Separation of 33kV Bus	----	----	----
Operation Aspect		◎ (O&M for Both GCCT's are conducted independantly)	○ (Need to adjust O&M between GCCT and two Bus's)	◎ (O&M for Both GCCT's are conducted independantly)	◎ (O&M for Both GCCT's are conducted independantly)
Equipment Aspect (Rough Cost)		◎ (Base:11/33kV Tr*3)	▲ (Addtion: 11/230kV Tr*2 - 11/33kV Tr *2)	▲ (Addtion: 11/230kV Tr*3 - 11/33kV Tr *3)	○ (Addtion: 11/33kV Tr *2)
Total Evaluation		▲	○	○	◎

Source: JICA Study Team

Judging from the comparison result, Option 4 seemed to be preferable among these connection options of generators tentatively from the several view aspects

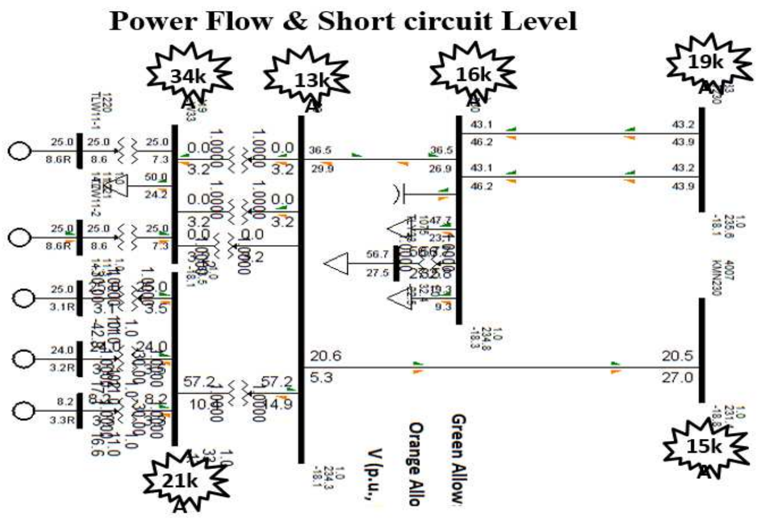
However, this Option 4 had some problems such as repairing of Control Building required etc.

Therefore, the additional connection cases base on the Option 4 was developed as the final recommendation connection method described hereafter for avoiding problems mentioned before in close cooperation with EPGE and DPTSC.

(5) Recommendation of TG Connection Method in Thilawa P/S

From considering the study results and all aspects concerned in total, the following TG Connection Method shown in Figure ES3.4-4 in Thilawa P/S was recommend finally through the considering steps mentioned above under close cooperation with related organization of Myanmar.

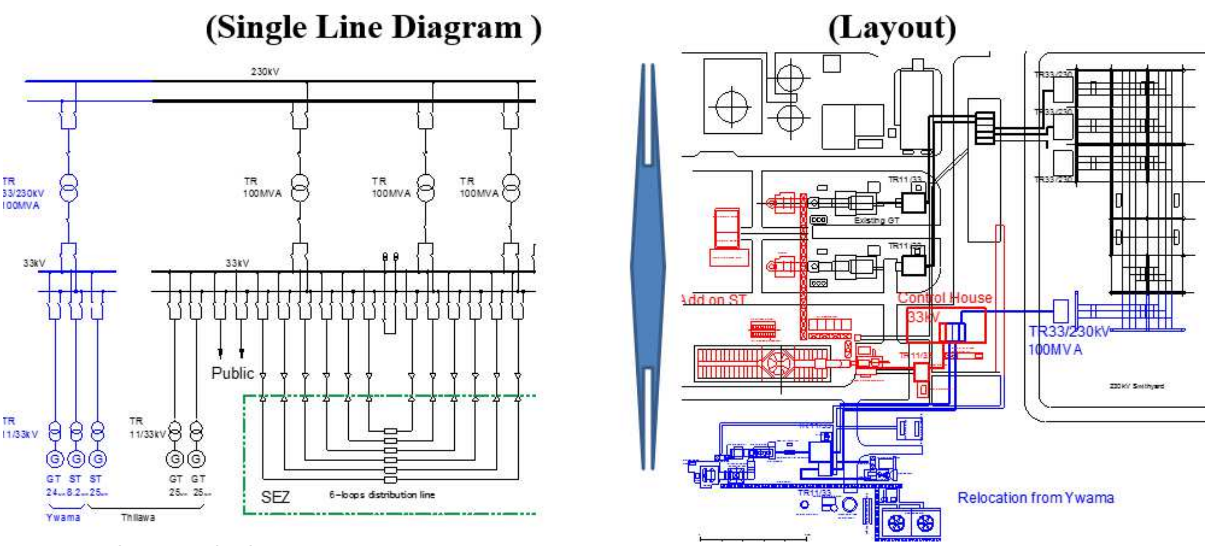
This TG Connection Method in Thilawa P/S seems to conquer almost all problems such as short circuit capacity problem etc.



Source: JICA Study Team

Figure ES3.4-4 Recommendation for TG Connection Method in Thilawa P/S

The single line diagram and Layout of this recommended connection method is shown again in Figure ES3.4-5 as well for references.



Source: JICA Study Team

Figure ES3.4-5 Single line diagram and Layout of this connection method

3.5 Civil and Building Works

Since the Thilawa Add-on Project and the Ywama Relocation Project are carried out on the same premises, it is important to consider the existing situation regarding civil engineering construction and plan a cooperation between the two projects.

For civil engineering work, it should be planned to make efficient construction by fully utilizing the construction experience of existing simple cycle power generation equipment.

In addition, it is necessary to formulate a cooperative plan as two projects when using existing buildings and preparing newly constructed buildings.

The contents of the main civil engineering construction work are described below.

- Installation of equipment foundations and building foundation
- Foundation will be supported with RC piles
- Installation of electrical and control building
- Pile driving by hydraulic driving machine (vibration-free method)
- Extension of existing boundary wall (if necessary)
- Installation of cable and pipe trenches
- Installation of duct banks
- Installation of concrete paved surface for maintenance area
- Installation of gravel paved surface
- Other necessary civil building works as required

4 Cost Estimation and Implementation Schedule of the Project

4.1 Project cost estimation

Estimated costs are shown below:

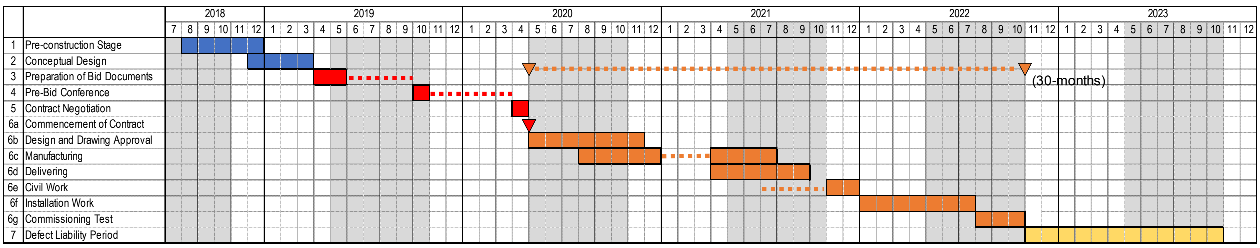
- Estimated cost of Add-on project: *This amount is not published at this public edition of the report.*
- Estimated cost of relocation project: *This amount is not published at this public edition of the report.*

The cost examination mentioned above seems to be generally appropriate based on the EIA (Energy Information Administration) cost data and actual project cost data available at published data (e.g. press release of project owner).

4.2 Implementation schedule

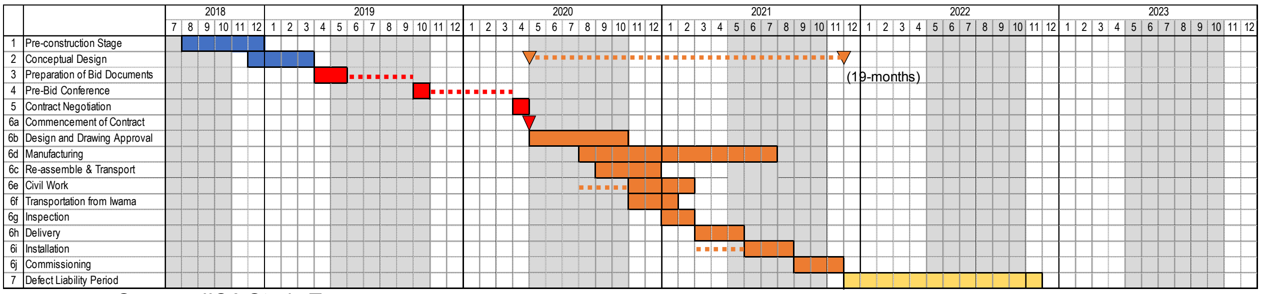
Estimated schedules are show below;

- Estimated cost of Add-on project: 30 months
- Estimated cost of relocation project: 24 months



Source: JICA Study Team

Figure ES4.2-1 Implementation schedule of Thilawa Add-on



Source: JICA Study Team

Figure ES4.2-2 Implementation schedule of Ywama Relocation

5 Environmental and Social Consideration

In this Chapter, 1) Environmental and social laws and regulations in Myanmar, 2) Environmental and social baseline conditions near the project, 3) Environmental and social consideration on the project implementation, 4) Environmental performance of the existing GTG project, 5) Demarcation of Myanmar side for the project implementation, 6) Cumulative impact assessment and 7) Issues to be solved and recommendation of the project are described.

5.1 Options of Project

The following options are compared and evaluated from 1) technical, 2) financial, economic, and 3) environmental aspects as shown in the following **Table ES5.1-1**.

Table ES5.1-1 Options for Comparison

Item	Option 1	Option 2	Option 3	Option 4
Characteristics	Combined cycle of the existing 2 GTs	Relocation of Ywama NEDO Unit (1GT+1ST)	Relocation and rehabilitation of GT from Ywama NEDO Unit/ Combined cycle of 3 GTs	Option 1 + 2
Composition of the plant GT:G:STG	2:2:1	2:2 (Existing) 1:1:1	3:3:1	2:2:1 + 1:1:1
Additional capacity (MW)	25	32.2	23.2+36.6 =59.8	25+32.2=57.2
Total planned capacity (MW)	75 (Existing 50, New 25)	82.2 (50+32.2)	109.8 (50+59.8)	107.2 (50+57.2)
Estimation of water consumption (ton/day) with ACC and WCC cooling method	250 (ACC) 3,340 (WCC)	83 (ACC) 1,104 (WCC)	375 (ACC) 5,010 (WCC)	333 (ACC) 4,444 (WCC)
Environment (air)	Gas emission from existing 2 GTs can comply with the target level.	It is necessary to check whether combination of gases from rehabilitation of 1 GT & ST from Ywama and existing 2 GTs can comply with the target level for emission or not.		
Environment (water use and ground subsidence)	Difficult to take groundwater due to shortage of groundwater resource and avoidance of ground subsidence. Necessary to take surface water (e.g., reservoir water/river water)			
Social	No resettlement, land acquisition, and income restoration.		No resettlement and land acquisition, and income restoration for existing land use plan of the project (It may be necessary for 1 or 2 households to assist income restoration such as crop compensation in case of using temporary construction yard around the project area)	

Source: JICA Study Team

5.2 Approval process of EIA for implementation of the proposed project

The expected time frame of the updating of EIA study for the upgrading project shown in the **Table ES5.2-1**. It may take totally about 12.5 months from the preparation for updating the draft EIA report to the obtaining of the Approval of EIA report issued by the MONREC after appraising by the National Environmental Conservation and Climate Change Central Committee (NECCCCC).

Table ES5.2-1 Expected Schedule of EIA study for the proposed project

No.	Description of Actions	Expected / Required Time Period	Remark
0	Completion of F/S Report		
1	Preparation for updating draft EIA Report	2 months	
2	Arranging public consultation, disclosure and finalization of EIA Report	2 months	
3	Submission of final EIA Report* and Appraisal	4.5 months	*MOEE's cover letter on request of urgent review shall be required.
4	Approval by NECCCCC*	4 months	* National Environmental Conservation and Climate Change Central Committee * Committee meeting organizes every 4 months

Source: JICA Study Team

5.3 Actions/Activities done by Myanmar Side

When the upgrading of the Thilawa Power Plant Project is started, the following actions/activities should be done from the Myanmar side (eg. MoEE/EPGE) as shown in the **Table ES5.3-1**.

Table ES5.3-1 Required Activities of MoEE/EPGE

No.	Activities	Remark
1.	Land compensation/resettlement/ income restoration/crop compensation	For the existing 10 ha project area (power plant and substation), TSMC grants usage rights to the MoEE. For future expansion of the land, TSMC and MoEE may cooperate for this activity.
2.	To discuss/negotiate with the relevant authorities to use of water such as water supply system and reservoir water	
3.	To attend stakeholder meeting, public consultation meetings in EIA study	
4.	To provide environmental related required information for the upgrading project	
5.	To conduct environmental monitoring and management during operation and maintenance	
6.	To make a greenbelt with trees and/or vegetation covers if the land is available.	

Source: JICA Study Team

5.4 Issues to be Solved and Recommendation of the Project

1) Assistance of Implementation of EIA Study

As mentioned above, it takes around one year to get an approval of the EIA study from the start of the preparation of the updated EIA report. In case that the EIA approval (including official confirmation of emission gas and noise standards by MONREC ECD) will be required at the timing before distribution of tender documents to the contractor, it may be necessary to start the preparation of updated EIA report before procurement of consultant for the detailed design or bidding by yen loan. Because MOEE requests JICA to support the preparation of the updated EIA report, it is necessary to consider the timing of the start of preparation and procurement of consultant for the EIA study, if necessary.

2) Application of NO_x Emission Standard

In case that the operation of upgrading project, the gas turbine from Ywama Power Station does not have water injection system for NO_x reduction, NO_x level from the gas turbine is expected to be at 60 ppm to 110 ppm same as NO_x level of the Thilawa Power Plant without water injection. In case that the average of NO_x level of the Thilawa Power Plant will be confirmed at less than 97 ppm without water injection based on enough NO_x monitoring data and around 25 ppm with water injection, the average of NO_x level will be at 49 ppm (25 ppm each from the two gas turbines in Thilawa and 97 ppm from the gas turbine of Ywama) in compliance with NEQG NO_x emission.

NEQG does not mention about detailed application of standards clearly such as application of the NO_x standard to emission of each unit of gas Turbine and to emission of average of the all gas Turbines (Average will be calculated by dividing total pollution load and total emission gas volume of three units. Pollution load is calculated by multiplying emission gas volume and concentration of emission gas from each unit and total pollution load is adding pollution load from each unit.). Thus, it is necessary to authorize the above standard application by MONREC ECD through discussion and appraisal process of the final updated EIA report.

3) Monitoring of application of water injection system for NO_x emission reduction in the existing Thilawa Power Plant

As mentioned above, the existing Thilawa Power Plant (25 MW x 2 units) has a function of water injection system to reduce NO_x emission. However, the injection system will be started after the water supply from Langunbyn Reservoir under the Yen Loan Project of Yangon Water Supply (Phase 1). Because water supply for the injection system is an essential point for the project to comply with NO_x emission concentration stipulated in NEQG, it is necessary to monitor the application of water injection system to the existing Thilawa Power Plant.

6 Financial and Economic Viability

6.1 Expected Impact of the Project (Operation and Effect Indicators)

Operation indicators are intended to evaluate the operational condition of the Project, which quantitatively checks whether the Project is being operated properly.

Table ES6.1-1 Operation Indicators (Option 1)

Indicator	Formula	Target
Plant load factor (%)	= Electricity generated per year /(rated output × hours per year) ×100	80%
Gross thermal efficiency	= (Gross electricity generated per year × 860) / (fuel consumption per year × heat release value of the fuel) × 100	More than 45%

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

Table ES6.1-2 Operation Indicators (Option 2)

Indicator	Formula	Target
Plant load factor (%)	= Electricity generated per year /(rated output × hours per year) ×100	80%
Gross thermal efficiency	= (Gross electricity generated per year × 860) / (fuel consumption per year × heat release value of the fuel) × 100	43%

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

Effect indicators are intended to evaluate outcome of the Project.

Table ES6.1-3 Effect Indicators (Option 1)

Indicator	Formula	Target
Net electric energy production (GWh)	As shown by the name of the indicator	175.2 GWh
Maximum output (MW)	As shown by the name of the indicator	25 MW

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

Table ES6.1-4 Effect Indicators (Option 2)

Indicator	Formula	Target
Net electric energy production (GWh)	As shown by the name of the indicator	225.7 GWh
Maximum output (MW)	As shown by the name of the indicator	32.2 MW

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

6.2 Financial and Economic Analysis

6.2.1 Objectives and Methodology of the Financial Analysis and Economic Analyses

The financial and economic analyses aim to examine the viability of the Project by calculating the IRR (Internal Rate of Return) and the NPV (Net Present Value) and are conducted for the selected options.

Financial analysis is conducted to evaluate the profitability of the Project from the viewpoint of the implementing organization (i.e. EPGE). To obtain the FIRR (Financial Internal Rate of Return) and the FNPV (Financial Net Present Value), net benefit of the project is calculated considering 1) the benefits i.e., incremental revenue of tariff from the Project and 2) the cost based on the market price.

Economic analysis is conducted to evaluate the viability of the Project from the viewpoint of the national economy. To obtain the EIRR (Economic Internal Rate of Return) and the ENPV (Economic Net Present Value), the benefit of the Project is calculated considering 1) the increased benefit based on the saved cost by replacing alternative energy sources (e.g., diesel generators) and 2) the economic costs.

6.2.2 Financial Analysis

Benefit and cost are compiled and calculated considering the 2017 prices in order to obtain the FIRR. Moreover, the rate of the treasury bill (8.8%) is used as the discount rate for calculating the FNPV. By using the discount rate, the FNPV of Option 1 turns into a positive value, while that of Option 2 becomes negative because the gas cost is incurred in the case of Option 2 and a shorter project life (20 years) is applied.

Table ES6.2-1 FIRR and FNPV

This table is not published at this public edition of the report.

	FIRR	FNPV (Million Kyat)	FNPV (Million $)
Option 1			
Option 2			
Total			

Source: JICA Study Team

Sensitivity analysis is conducted for the financial analysis as the actual condition may be different from those assumed for the base case. In the sensitivity analysis, 1) cost increase (+10%) and 2) delay in construction (1 year) are considered.

Table ES6.2-2 Sensitivity Analysis for Financial Analysis (Option 1)

This table is not published at this public edition of the report.

Case	Benefit	Cost	FIRR	FNPV	
			(%)	(Mil Kyat)	(Mil US$)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: JICA Study Team

Table ES6.2-3 Sensitivity Analysis for Financial Analysis (Option 2)

This table is not published at this public edition of the report.

Case	Benefit	Cost	FIRR	FNPV	
			(%)	(Mil Kyat)	(Mil US$)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: JICA Study Team
Note: The cost includes both the financial cost during construction period and O&M cost.

The FNPV of Option 1 remains positive in all cases of sensitivity analysis. On the other hand, the FNPV of Option 2 are negative in all cases of sensitivity analysis, reflecting the fact that incremental gas cost is incurred for Option 2 and it reduces the profit margin.

6.2.3 Economic Analysis

The economic benefit and cost are compiled and calculated in order to obtain EIRR and are discounted using the social discount rate (12%) for attaining the ENPV.

Table ES6.2-4 EIRR and ENPV

This table is not published at this public edition of the report.

	EIRR	ENPV (Million Kyat)	ENPV (Million $)
Option 1			
Option 2			
Total			

Source: JICA Study Team
Note: EIRR and ENPV of Total (Option 1+Option 2) are calculated based on 30 years of project life.

The result shows that EIRR of both options is higher than the cut-off rate in the base case. The ENPV of the Project of both options shows a positive result. The Project can be justified from the viewpoint of improving the national economy.

The sensitivity analysis is conducted for economic analysis. The cost increase and delay in construction are considered.

Table ES6.2-5 Sensitivity Analysis for Economic Analysis (Option 1)

This table is not published at this public edition of the report.

Case	Benefit	Cost	EIRR	ENPV	
			(%)	(Mil. Kyat)	(Mil. US$)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: JICA Study Team.
Note: The cost includes both the economic cost during construction period and O&M cost.

Table ES6.2-6 Sensitivity Analysis for Economic Analysis (Option 2)

This table is not published at this public edition of the report.

Case	Benefit	Cost	EIRR	ENPV	
			(%)	(Mil. Kyat)	(Mil. US$)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: JICA Study Team.
Note: The cost includes both the economic cost during construction period and O&M cost.

The impact on EIRR and ENPV of the change in the level of cost and delay in construction is small with slight change of EIRR and ENPV.

Chapter 7 Capability of the Government of Myanmar for the Project

In this Chapter, 1) Overview of the implementation organization, 2) Organizational chart for the project implementation, 3) Study on capability of EPGE for the project implementation, and 4) training in Japan are described.

By examining current situation of capability and operational situation, contents of training program are proposed.

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စုစည်းထားသော အဓိကအချက်များ

အခန်း (၁) ယေဘုယျ နောက်ခံသမိုင်းကြောင်း

ဤအခန်းတွင် (၁) တွင် စီးပွားရေး နှင်. ဘဏ္ဍာရေး အခြေအနေ (၂) မြန်မာနိုင်ငံရှိ လျှပ်စစ်ဓါတ်အား ကဏ္ဍအား သုံးသပ်ခြင်း တို.ကို ဖော်ပြထားသည်။

မြန်မာနိုင်ငံရှိ အဓိက ဓာတ်အားအရင်းအမြစ်များမှာ ရေအား (၆၀%) နှင်. ဓါတ်ငွေ. (၄၀%) တို.ဖြစ်သည်။

ယခင်က ဓာတ်အား၏ ၇၀% ကျော်ကို ရေအားဖြင်. ပေးဝေခဲ့သည်။ သို.သော်လည်း ရာခိုင်နှုန်းသည် ဓါတ်ငွေ.ဓါတ်အားပေးစက်ရုံ အသစ်တည်ဆောက်ခြင်းကြောင်. လျှပ်စစ်ဝယ်လိုအား တိုးမြင့်လာမှု နှင့် ကိုက်ညီစေရန် ဓာတ်အားပေး စက်ရုံအသစ် တပ်ဆင်ခြင်းကြောင့်၊ ဓာတ်အားရာခိုင်နှုန်း တဖြည်းဖြည်းကျဆင်း လာသည်။ ၂၀၁၆ ခုနှစ်တွင် ရေအားလျှပ်စစ်၏ အစုရှယ်ယာသည် (၅၈.၆%) ဖြစ်သည်။

လျှပ်စစ် ဝယ်လိုအားများပြားလာခြင်းအား အမှီလိုက်ရန်၊ မြန်မာနိုင်ငံတွင် ဓါတ်အားထုတ်လုပ်မှုသည် ၁၃% တိုးတက်ကြီးထွားလာသည်။ နှစ်စဉ် ဓါတ်အားထုတ်မှုသည် ၂၀၁၀-၁၁ ဘဏ္ဍာရေးနှစ်တွင် ၈၅၉၈.၁ GWh ရှိပြီး၊ ၂၀၁၅-၁၆ ဘဏ္ဍာရေးနှစ်တွင် ၁၅၈၆၄.၈ GWh ရှိသည်။

အခန်း (၂) စစ်တမ်းမူဂါဒ

ဤအခန်းတွင် (၁) စစ်တမ်း၏ နောက်ခံသမိုင်းကြောင်း နှင့် ရည်ရွယ်ချက်၊ (၂) အဆိုပါ ကဏ္ဍနှင့် ဧရိယာ၏ လက်ရှိ အခြေအနေ၊ (၃) လေ့လာမှု အကြောင်းအရာများ၊ (၄) လေ့လာမှု မူဂါဒ နှင့် စစ်တမ်း ပြီးစီးအောင်ဆောင်ရွက်ခြင်း နည်းစနစ် စသည်တို့ကို ဖော်ပြထားပါသည်။

လေ့လာတွေ.ရှိချက်များ သည် အောက်ဖော်ပြပါ အကြောင်းအရာ (၃)ချက် ဖြစ်သည်။

- အကြောင်းအရာ ၁ ။ ။သီလဝါ အထူးစီးပွားရေးဇုန် အနီးအနားတွင် ဓါတ်အားထုတ်လွှတ်ခြင်း၊ ဖြန်.ဖြူးခြင်း လိုင်း နှင့် ခွဲရုံအဆောက်အဦးများ။
- အကြောင်းအရာ ၂ ။ ။ ရန်ကုန်တွင် ဓါတ်အား ဝယ်လိုအား နှင့် ထောက်ပံ့ခြင်းကြား ကွာဟမှု။
- အကြောင်းအရာ ၃ ။ ။ ထပ်တိုး HRSG နှင့် ST တပ်ဆင်ခြင်းအတွက် ရေထောက်ပံ့ခြင်း။ အဆိုပါ

အကြောင်းအရာများ အတွက်၊ စစ်တမ်းမူဂါဒ (၃) ချက်ကို ပြဋ္ဌာန်းခဲ့သည်။

- မူဂါဒ ၁ ။ ။တည်ရှိနေသော national grid အား လေ့လာခြင်း၊ ပြဿနာများအား ခွဲခြားခြင်း နှင့် တန်ပြန်ရေး အစီအမံများအား တင်ပြခြင်း။
- မူဂါဒ ၂ ။ ။ Master Plan တိုးတက်ခြင်းအား အတည်ပြုခြင်း နှင့် Supporting Plan အား လေ့လာခြင်း။
- မူဂါဒ ၃ ။ ။ ရေအရင်းအမြစ်နှင့် ရေသုံးစွဲမှုလျှော့ချခြင်း နှင့် အသုံးပြုခြင်းအား လေ့လာခြင်း။

အောက်ဖော်ပြပါအတိုင်း လေ့လာမှုကို အဆင့် (၃) ဆင့်ဖြင့် စီမံခန်.ခွဲထားပါသည်

- အဆင့် (၁)။ ။ ယခုလက်ရှိ အခြေအနေအား အတည်ပြုခြင်း နှင့် ပြဿနာများအား ခွဲခြားခြင်း။
- အဆင့် (၂)။ ။ အယူအဆအပေါ် အခြေတည်သော ဒီဇိုင်း။
- အဆင့် (၃)။ ။ နောက်ဆုံးအစီအရင်ခံစာများ နှင့် ဆွေးနွေးမှု များ ပြင်ဆင်ခြင်း။

အခန်း (၃) စီမံကိန်းအတွက်ကြိုတင်ပြင်ဆင်ခြင်း နှင့် နည်းပညာပိုင်းဆိုင်ရာ ဖြစ်နိုင်ခြေ

အခန်းတွင် စီမံကိန်းအတွက်ကြိုတင်ပြင်ဆင်ခြင်းနှင့် နည်းပညာပိုင်းဆိုင်ရာ ဖြစ်နိုင်ချေများကို ဆန်းစစ် ဖော်ပြထားသည်။

၃.၁ စီမံကိန်းအကောင်အထည်ဖော်ရန်အတွက် လေ့လာရမည့်အချက်များ

အောက်ဖော်ပြပါ ရွေးချယ်စရာအချက်များအား (၁) နည်းပညာပိုင်းဆိုင်ရာ (၂) ဘဏ္ဍာရေးနှင့် စီးပွားရေးဆိုင်ရာ (၃) သဘာဝပတ်ဝန်းကျင်နှင့် လူမှုရေးဆိုင်ရာ ရှုထောင့်တို့မှ နှိုင်းယှဉ်၍ ချင့်ချိန်ရမည်။

ဇယား ES၃.၁-၁ ရွေးချယ်စရာအချက်များ နှိုင်းယှဉ်ခြင်း

ရွေးချယ်စရာအချက်များ နှိုင်းယှဉ်ခြင်း	ရွေးချယ်မှု ၁	ရွေးချယ်မှု ၂	ရွေးချယ်မှု ၃	ရွေးချယ်မှု ၄
သွင်ပြင်လက္ခဏာ	တည်ရှိဆဲ GT ၂လုံး ပေါင်းစပ်လည်ပတ်ခြင်း	ရွာမမှ GT ၁လုံးနှင့် ST ၁လုံး အား နေရာပြောင်းရွှေ့၍ ပြန်လည်ဆင့်မြှင့်တင်ခြင်း	၁။ ရွာမမှ GT အား နေရာပြောင်းရွှေ့၍ပြန်လည် အဆင့်မြှင့်တင်ခြင်း။ ၂။ GT ၃လုံး အဖြစ် ပေါင်းစပ်လည်ပတ်ခြင်း	ရွေးချယ်မှု ၁ + ရွေးချယ်မှု ၂
စက်ပစ္စည်းပေါင်းစပ်ဖွဲ့ စည်းခြင်း (GT:G:STG)	၂း၂း၁	၂း၂ (တည်ရှိဆဲ) ၁း၁း၁	၃း၃း၁	၂း၂း၁ ၁း၁း၁
အပိုရရှိနိုင်မည့် ပမာဏ (MW)	၂၅ (ST)	၂၃.၂ (GT) + ၉.၀ (ST)	၂၃.၂ (GT) + ၃၆.၆ (ST)	၂၅(ST) + ၂၃.၂(GT) + ၉.၀(ST)
စုစုပေါင်းရမည့် ပမာဏ (MW)	၇၅ (၅၀+၂၅)	၈၂.၂ (၅၀+၃၂.၂)	၁၀၉.၈ (၅၀+၅၉.၈)	၁၀၇.၂ (၅၀+၅၇.၂)
ခန့်မှန်း ရေသုံးစွဲမှုနှုန်း (တန်/နာရီ)	၂၅၀ (ACC) ၃၃၄၀ (WCC)	၈၃ (ACC) ၁၁၀၄ (WCC)	၃၇၅ (ACC) ၅၀၁၀ (ACC)	၃၃၃ (ACC) ၄၄၄၄ (WCC)
EPC ကုန်ကျစရိတ် (မီလီယံ ဒေါ်လာ)	***	***	ရွေးချယ်မှု ၄ ထက် နည်းသည်။	***
သဘာဝပတ်ဝန်းကျင် (လေ)	တည်ရှိနေသော GT ၂လုံးမှ ထွက်သော ဓာတ်ငွေ့သည် သတ်မှတ်ထားသော အဆင့် နှင့် ကိုက်ညီနိုင်သည်။	ရွာမမှ ပြန်လည်အဆင့်မြှင့်တင်မည့် GT ၁လုံးနှင့် ST ၁ လုံး မှ ဓာတ်ငွေ့ထုတ်လွှတ်မှုသည် သတ်မှတ်အဆင့်နှင့် ကိုက်ညီမှုရှိမရှိ စစ်ဆေးရန်လိုအပ်သည်။	လက်ငံဘက်တွင် ဖော်ပြထားသည့် အချက်အလက်အတိုင်းဖြစ်သည်။	လက်ငံဘက်တွင် ဖော်ပြထားသည့် အချက်အလက်အတိုင်းဖြစ်သည်။
သဘာဝပတ်ဝန်းကျင် (ရေ အသုံးပြုမှုနှင့် မြေသား ကျွံခြင်း)	မြေအောက်ရေ အရင်းအမြစ် ပြတ်လပ်မှု နှင့် မြေသားကျွံခြင်းကို ရှောင်ရှားနိုင်ရန် မြေအောက်ရေကို ထုတ်ယူသုံးစွဲရန် ခက်ခဲသည်။ မြေပေါ်ရေကို အသုံးပြုရန်လိုအပ်သည်။	လက်ငံဘက်တွင် ဖော်ပြထားသည့် အချက်အလက်အတိုင်းဖြစ်သည်။	လက်ငံဘက်တွင် ဖော်ပြထားသည့် အချက်အလက်အတိုင်းဖြစ်သည်။	လက်ငံဘက်တွင် ဖော်ပြထားသည့် အချက်အလက်အတိုင်းဖြစ်သည်။
လူမှုရေး	ပြန်လည်နေရာချထားပေးခြင်း၊ရရှိလာသောဝင်ငွေများအား ပိုင်ရှင်ထံ ပြန်ပေးခြင်းမရှိပါ။	ပြန်လည်နေရာချထားပေးခြင်း၊ရရှိလာသောဝင်ငွေများ အား ပိုင်ရှင်ထံ ပြန်ပေးခြင်းမရှိပါ။	ပြန်လည်နေရာချထားခြင်း၊ အတတ်ပညာမျှဝေခြင်း များမရှိပါ။ဝင်ငွေများအားမူလပိုင်ရှင် အပ်နှံရန်လိုအပ်သည်။ (သို့သော် အိမ်ထောင်စု ၁၈ (သို့) ၂၈ သာ)	ပြန်လည်နေရာချထားခြင်း၊ အတတ်ပညာမျှဝေခြင်း များမရှိပါ။ဝင်ငွေများအားမူလပိုင်ရှင် ပ်နှံရန်လိုအပ်သည်။ (သို့သော် အိမ်ထောင်စု ၁၈ (သို့) ၂၈ သာ)
တည်ဆောက်မည့် အချိန်ကာလ	၂၄လ မှ ၃၀လ	၁၉လ	၃၆လ	၃၀လ

Source: Prepared by the JICA Study Team

၃.၂ စက်ပိုင်းဆိုင်ရာ လိုအပ်သည့်အထောက်အပံ့များ ကြိုတင်ပြင်ဆင်ခြင်းနှင့် စက်ကိရိယာများ မွမ်းမံခြင်းလုပ်ငန်း

ကွင်းဆင်းစူးစမ်းလေ့လာမှုများပေါ် မူတည်၍ စက်ပိုင်းဆိုင်ရာ လိုအပ်သည့်အထောက်အပံ့များ ကြိုတင်ပြင်ဆင်ခြင်းနှင့် စက်ကိရိယာများ မွမ်းမံခြင်းလုပ်ငန်းများအား အဆိုပြုပါသည်။

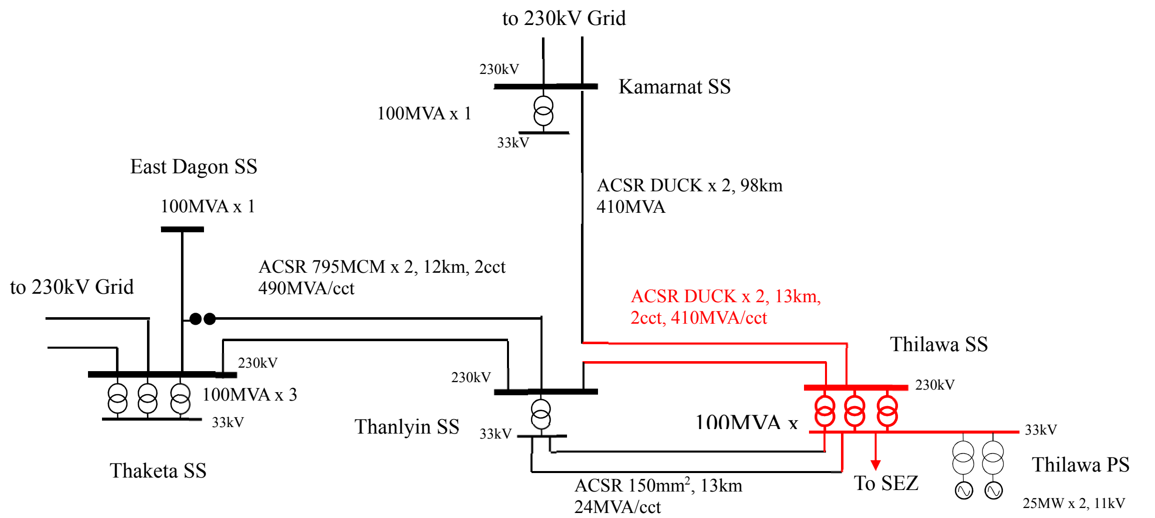
(နောက်ဆုံးအစီရင်ခံစာအပြီးသတ်ပြီးနောက် ပြင်ဆင်ရန်)

၃.၃ ဓာတ်အား ထုတ်လွှတ်ခြင်းစနစ်

မြန်မာနိုင်ငံသည် ရေစွမ်းအင် အရင်းအမြစ် ကြွယ်ဝသော်လည်း ၄င်းတို့ အများစုမှာ နိုင်ငံအလယ်ပိုင်း နှင့် မြောက်ပိုင်းတွင်သာ စုစည်းနေကြသည်။ ရန်ကုန်မြို့၏ လျှပ်စစ်ဓာတ်အား ဖြန့်ဖြူးရေးဌာနသည် နိုင်ငံ အလယ်ပိုင်းနှင့် မြောက်ပိုင်းမှ ရေအားလျှပ်စစ်ကို ၂၃၀ kV မဟာဓာတ်အားလိုင်းများဖြင့် ရယူသည်။ လျှပ်စစ်ဓာတ်အားကို နိုင်ငံမြောက်ပိုင်းမှ ရယူရုံမျှ မကဘဲ ရန်ကုန်မြို့၏ လျှပ်စစ်ဓာတ်အား လိုအပ်ချက်ကို ဖြည့်ဆည်းနိုင်ရန် လှော်ကား၊ သာကေတ၊ ရွာမ နှင့် အလုံ တို့တွင်လဲ အဓိကဓာတ်အားပေးစက်ရုံများ လည်ပတ်၍ ဓာတ်အား ထောက်ပံ့လျက်ရှိသည်။

သီလဝါအထူးစီးပွားရေးဇုန် အတွက် လျှပ်စစ်ဓာတ်အားကို ယခုအခါ ၂၅ မဂ□ါဝပ်ထုတ်လွှတ်နိုင်သည့် သဘာဝဓာတ်ငွေ့သုံး တာဘိုင် ဓာတ်အားပေးစက် (၂) လုံးတပ်ဆင်ထားသော သီလဝါလျှပ်စစ်ဓာတ်အားပေး စက်ရုံ နှင့် MJTD မှ ၁၃ ကီလိုမီတာကွာဝေးသော သန်လျင်ဓာတ်အားခွဲရုံတို့မှလဲ ၃၃kv Single Circuit လိုင်း (၂) လိုင်းဖြင့် ရရှိလျက်ရှိသည်။ ၃၃ kv လိုင်းတစ်လိုင်းချင်းစီတွင် ဓာတ်အားထုတ်လွှတ်မှု အများဆုံးပမာဏ ၂၄MVA ကို ခံနိုင်သော လျှပ်ကူးပစ္စည်း (Conductor) ACSR ၁၅၉mm2 တပ်ဆင်ထားသည်။

၂၃၀/၃၃kV သီလဝါဓာတ်အားခွဲရုံအသစ်နှင့် ၂၃၀KV ၂cct ဓာတ်အားလိုင်းများအား ဆောက်လုပ် သွယ်တန်းလျက်ရှိရာ သီလဝါဓာတ်အားပေးစက်ရုံနှင့် SEZ သည် မြန်မာနိုင်ငံ၏ ပင်မဓာတ်အားလိုင်း ကွန်ရက်နှင့်ချိတ်ဆက်ထားသော သန်လျင်နှင့် ကမာနက် ဓာတ်အားခွဲစက်ရုံတို့ဖြင့် ချိတ်ဆက်နိုင် တော့မည်ဖြစ်သည်။



Source: Prepared by the JICA Study Team

ပုံ ES၃.၃-၁ ၂၀၁၇ ခုနှစ်တွင် သီလဝါ ဓာတ်အားခွဲရုံ အပြီးသတ်ပြီးနောက် သီလဝါ အထူးစီးပွားရေးဇုန်သို့ ဓာတ်အားပို့လွှတ်မည့် ဓာတ်အားစနစ်

သီလဝါ ဓာတ်အားပေးစက်ရုံ ပြန်လည် လည်ပတ်နိုင်လျှင် အောက်ပါ ဓာတ်အားပေးစက် (၃) လုံးသည် လက်ရှိ၃၃kv bus system တွင် လျှစ်စီးပတ်လမ်းတို ဖြစ်ခြင်းကို ရှောင်ရှားနိုင်ရန် သီးခြား ၃၃KV bus bar system တွင် ချိတ်ချက်သင့်သည်။

- ရွာမ P/S မှ သဘာဝဓာတ်ငွေ့သုံး တာဘိုင်အတွက် ဓာတ်အားထုတ်စက် (၂၃.၂MW)
- ရွာမ P/S မှ သဘာဝရေနွေးငွေ့သုံး တာဘိုင်အတွက် ဓာတ်အားထုတ်စက် (၉MW)
- သီလဝါ P/S မှ တည်ရှိနေပြီးသော ဓာတ်ငွေ့သုံး တာဘိုင် (၂)ခု တွင် ရေနွေးငွေ့သုံး တာဘိုင် ထပ်ထည့်ရန် ဓာတ်အားထုတ်စက် (၂၅MW)

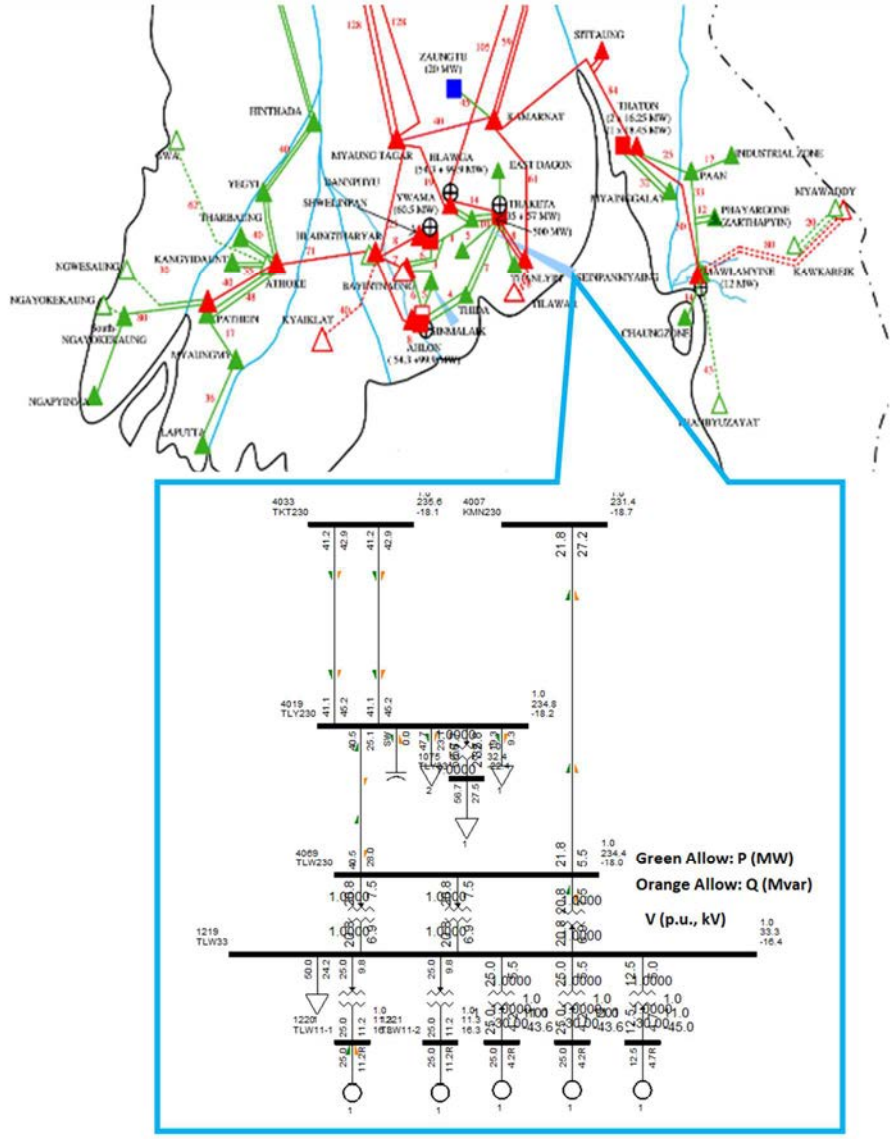
၃.၄ လျှပ်စစ်ဓာတ်အားပေးစနစ် ပေါ်တွင် စီမံကိန်း၏ အကျိုးသက်ရောက်မှုအား ချင့်ချိန်ခြင်း

လျှပ်စစ်ဓာတ်အားပေးစနစ်ပေါ်တွင် စီမံကိန်း၏ အကျိုးသက်ရောက်မှုအား PSSE software ကို အသုံးပြုထားသော Power System Analysis အပေါ်အခြေခံ၍ ချင့်ချိန်ရမည်။

လျှပ်စစ်ဓာတ်အားပေးစနစ်ပေါ်တွင် စီမံကိန်း၏ အကျိုးသက်မှု ချင့်ချိန်ရာ၌ သီလဝါဓာတ်အားပေးရုံနှင့် ရန်ကုန်မြို့တွင်းဧရိယာ အပါအဝင် ဒေသတွင်းရှိ ဓာတ်အားပေးစနစ်များကို အောက်ပါ ရှုထောင့်များမှ နေ၍ လုပ်ဆောင်ရမည်။ System stability analysis ကို DPTSC မှပေးသော သတင်းအချက်အလက်များ အပေါ်အခြေခံ၍ လုပ်ဆောင်ရမည်။

(၁) စီမံကိန်းနှင့် သက်ဆိုင်သော ဒေသတွင် လျှပ်စစ်ဓာတ်အားပေးစနစ်အား ပြန်လည်ဆန်းစစ်ခြင်း

ဒေသတွင်းလျှပ်စစ်ဓာတ်အားစနစ်ဖွံ့ဖြိုးတိုးတက်ရေးအစီအစဉ်အရ သီလဝါ ဓာတ်အားခွဲရုံသည် သာကေတ ဓာတ်အားခွဲရုံနှင့် ချိတ်ဆက်မည်ဖြစ်သော်လည်း သန်လျင် ဓာတ်အားခွဲရုံသည် ၂၃၀kv ဓာတ်အားလိုင်းနှင့် ချိတ်ဆက်မည်ဖြစ်သည်။



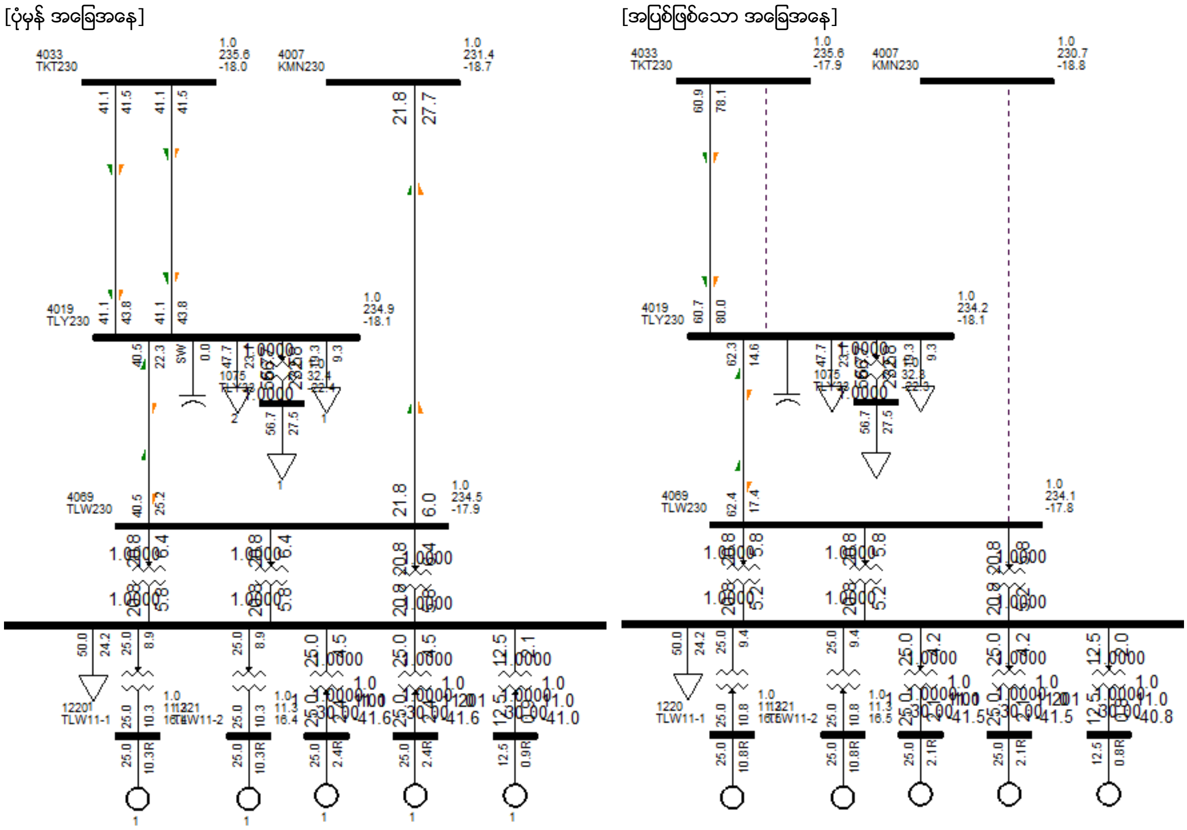
Source: Prepared by the JICA Study Team based on the map provided by DPTSC

ပုံ ES၃.၄-၁ ချင့်ချိန်ခြင်းလုပ်ငန်းအတွက် ဖွဲ့စည်းမှုစနစ်

(၂) လျှပ်စစ်ဓာတ်အား စီးဆင်းမှု ရှုထောင့်

ဓာတ်အားစီးဆင်းမှု ခွဲခြမ်းစိတ်ဖြာခြင်း (Power Flow analysis) အရ သီလဂါ ဓာတ်အားပေးစက်ရုံ ပြန်လည် လည်ပတ်ခြင်းနှင့် ဓာတ်အားထုတ်ရန်အတွက် ထောက်ပံ့ခြင်း ပြီးပါက အောက်ပုံတွင် ဖော်ပြထားသော ရလဒ်များ ရရှိရမည်။

ဓာတ်အားနည်းပညာခွဲခြမ်းစိတ်ဖြာ (Power system analysis) လေ့လာမှုပေါ် မူတည်၍ သတ်မှတ်ထားသော စုပေါင်းအဆင့် (band level) တွင် ဗို့အား ထိန်းထားနိုင်ရန်အတွက် သီလဂါ ဓာတ်အားပေးစက်ရုံနှင့် ၄င်းနှင့်ဆက်နွယ်နေသော ဒေသတွင်း လျှပ်စစ်ဓာတ်အားပေးစနစ်၏ ဓာတ်အားခွဲရုံများတွင် တပ်ဆင်ရမည့် shunt ဓာတ်ပေါင်းဖို (shunt reactor) (သို့) condenser များအား တပ်ဆင်ရန်မလိုအပ်ပေ။



Source: Prepared by the JICA Study Team

ပုံ ES၃.၄-၂ ပုံမှန်အခြေအနေနှင့် အနှောင့်အယှက်ရှိသော အခြေအနေတွင် ဓာတ်အားစီးမှုအား အနီးစပ်ဆုံးပုံစံတူပြုလုပ်လေ့လာထားသော ရလဒ်

(၃) လျှပ်စီးပတ်လမ်းတိုပမာဏအား ချင့်ချိန်ခြင်း

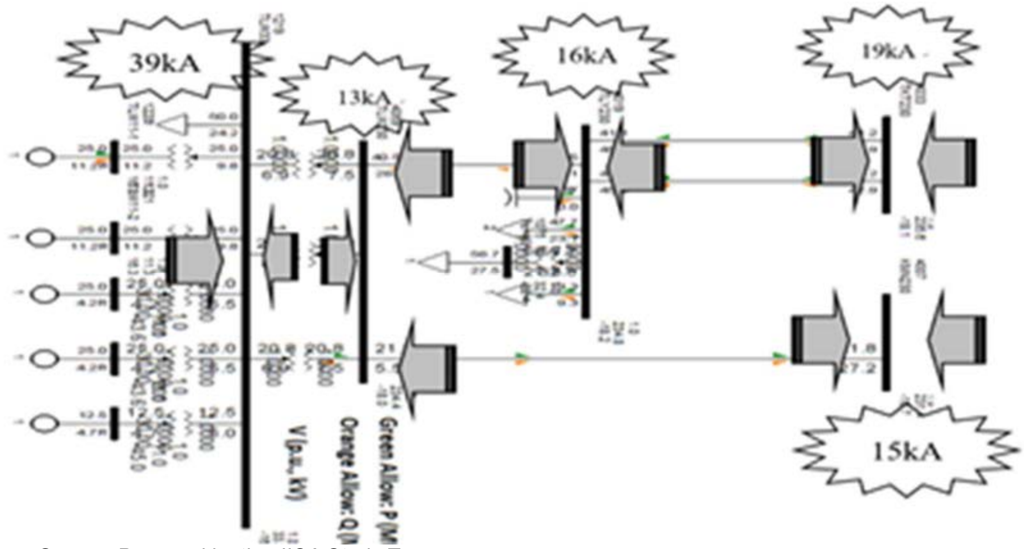
ပြင်းထန်သောကိစ္စများကို ထည့်သွင်းစဉ်းစား၍ အနီးစပ်ဆုံးပုံတူပြုလုပ်လေ့လာပြီး ရရှိလာသော ရလဒ်များမှ ခန့်မှန်းရာတွင် သီလဂါဓာတ်အားပေးစက်ရုံ ပြန်လည် လည်ပတ်ပြီးနောက် ပြင်းထန်သောပြဿနာမျိုး မဖြစ် နိုင်ပေ။ အဘယ်ကြောင့်ဆိုသော် ၃၃kv ၏ လျှပ်စီးပတ်လမ်းတိုတန်ဖိုးသည် ၃၃kv circuit breaker ခံနိုင်ရည် (၄၀kA) အောက် လျော့နေသော ကြောင့်ဖြစ်သည်။

သို့သော် ၃၃kv စနစ်၏ circuit breaker အဆင့်သည် အမြင့်ဆုံးလျှပ်စီးပတ်လမ်းတို၏ အဆင့်သို့ ရောက်လုနီးပါးဖြစ်နေသည်။ ထို့ကြောင့် လိုအပ်လျှင် ဓာတ်အားပေးစက်ရုံနှင့် လျှပ်တာပြောင်း တို့တွင် အတွင်းလျှပ်စစ်ဟန့်တားပစ္စည်းကဲ့သို့ တိကျသော လျှပ်စစ်ဟန့်တားပစ္စည်းများ သုံးခြင်း နှင့် လျှပ်စစ် ဟန့်တားမှုမြင့်သောပစ္စည်းများကို ထပ်တိုးဓာတ်အားပေးစက်အတွက်

လျှပ်တာပြောင်းများတွင်သုံးခြင်း (သို့) သီလဂါ လျှပ်စစ်ဓာတ်အားပေးစက်ရုံရှိ generator ၏ ချိတ်ဆက်မှု (Connection) ပြောင်းသောနေရာများ တွင် သုံးခြင်းတို့ကို အကြံပြုပါသည်။

နောက်တွင်ဖော်ပြထားသည့်အတိုင်း O&M နှင့် တပ်ဆင်မှုကုန်ကျစရိတ် သက်သာသောကြောင့် လျှပ်စစ်ဟန့်တားမှု မြင့်သော ပစ္စည်းများကို လက်ခံမည့်အစား ၃၃kv bus ၏ လျှပ်စီးပတ်လမ်းတို ကို လျှော့ချနိုင်မည့် အချို့သော ဓာတ်အားပေးစက်များကိုလည်း ချင့်ချိန်သင့်သည်။

အခြားတစ်ဖက်တွင်လည်း ၂၃၀kv bus နှင့် ပတ်သက်၍ ပုံတွင်ပြထာသည့်အတိုင်း ပြဿနာတစ်စုံတရာမရှိပါ။



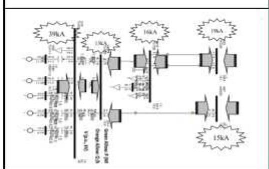
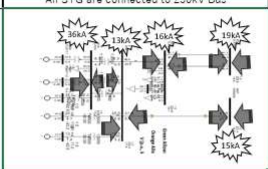
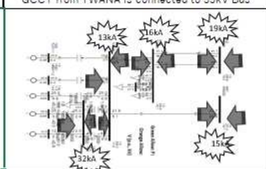
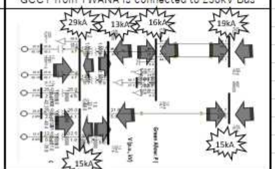
Source: Prepared by the JICA Study Team

ပုံ ES၃.၄-၃ ၃၃ kv နှင့် ၂၃၀ kv bus တို့၏ လျှပ်စီးပတ်လမ်းတိုတန်ဖိုး

(၄) သီလဂါ ဓာတ်အားပေးစက်ရုံတွင် ဓာတ်အားပေးစက် အစမ်းချိတ်ဆက်မှု ရွေးချယ်ခြင်း

အထက်တွင်ဖော်ပြခဲ့သော သီလဂါ ဓာတ်အားပေးစက်ရုံရှိ ၃၃kv bus ၏ လျှပ်စီးပတ်လမ်းတိုအဆင့်အား လျှော့ချနိုင်ရန်အတွက် သီလဂါ ဓာတ်အားပေးစက်ရုံရှိအချို့သော ဓာတ်အားပေးစက်များ၏ connection option များ ပေါင်းစပ်ခြင်းအား လုပ်ဆောင်၍ အောက်ပါဇယားတွင်ဖော်ပြထားသော connecton ပေါင်းစပ် ခြင်းများဖြင့် နိူင်းယှဉ်ရမည်။

ဇယား ES၃.၄-၁ သီလဂါဓာတ်အားပေးစက်ရုံရှိ ဓာတ်အားပေးစက် Connection ရွေးချယ်မှု နှိုင်းယှဉ်ခြင်း

Option NO		Option 1	Option 2	Option 3	Option 4
Configulation		All Generators are connected to 33kV Bus	All GTG are connected to 33kV Bus All STG are connected to 230kV Bus	Thilawa GCCT is connected to 230kV Bus GCCT from YWANA is connected to 33kV Bus	Thilawa GCCT is connected to 33kV Bus GCCT from YWANA is connected to 230kV Bus
					
Short Circuit Aspect	Evaluation (Max Current)	▲ (39kA at THILAWA 33kV Bus)	○ (36kA at THILAWA 33kV Bus)	○ (32kA at THILAWA 33kV Bus)	◎ (29kA at THILAWA 33kV Bus)
	Countermeasure	・Adaptopn of High Inpedance to Step-Up Tr of G ・Srilas Reactol between 33kV Buses or Separation of 33kV Bus	----	----	----
Operation Aspect		◎ (O&M for Both GCCT's are conducted indepandantly)	○ (Need to adjust O&M between GCCT and two Bus's)	◎ (O&M for Both GCCT's are conducted indepandantly)	◎ (O&M for Both GCCT's are conducted indepandantly)
Equipment Aspect (Rough Cost)		◎ (Base:11/33kV Tr*3)	▲ (Addtion: 11/230kV Tr*2 - 11/33kV Tr *2)	▲ (Addtion: 11/230kV Tr*3 - 11/33kV Tr *3)	○ (Addtion: 11/33kV Tr *2)
Total Evaluation		▲	○	○	◎

Source: Prepared by the JICA Study Team

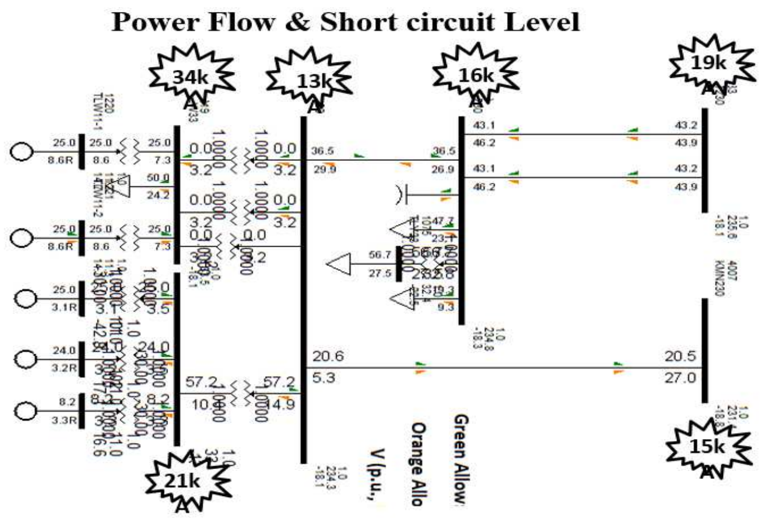
အောက်ပါ ရှုထောင့်များမှ ခန့်မှန်းချက်အရ ရွေးချယ်မှု (၄) သည် လျှပ်စစ်ဓာတ်အားပေးစက်၏ connection option များအနက် ပို၍ကောင်းသော ရွေးချယ်မှုဖြစ်သည်။

သို့သော်လည်း ရွေးချယ်မှု (၄) တွင် ထိန်းချုပ်မှု အဆောက်အဦး ပြုပြင်ရန် လိုအပ်ခြင်း ကဲ့သို့သော ပြဿနာအချို့ရှိနေသည်။ ထို့ကြောင့် ရွေးချယ်မှု (၄) တွင် အခြေခံသော ထပ်တိုးချိတ်ဆက်မှုအား EPGE နှင် DPTSCတို့နှင့်ပူးပေါင်းလုပ်ဆောင်မမတိုင်မီ ဖော်ပြထားသော ပြဿနာများအားရှောင်ကျဉ်ရန်နောက်ပိုင်းတွင် အကြံပြုမည့် နည်းလမ်းအတိုင်း ဖွံ့ဖြိုးအောင် ဆောင်ရွက်ရမည်။

(၅) သီလဝါ ဓာတ်အားပေးစက်ရုံတွင် TG Connection နည်းလမ်းအား အကြံပြုခြင်း

လေ့လာမှု၏ရလဒ်များ နှင့် ရှုထောင့်အားလုံးအား ခြုံငုံ သုံးသပ်ခြင်းအရ အောက်ပါပုံတွင် ဖော်ပြထားသော TG Connection နည်းလမ်းအား မြန်မာအဖွဲ့အစည်းများနှင့် ဆက်နွယ်သော ပူးပေါင်းဆောင် ရွက်မှုများအောက်တွင် အထက်ဖော်ပြပါ အဆင့်အတိုင်း သုံးသပ်စဉ်းစားရန် အကြံပြုပါသည်။

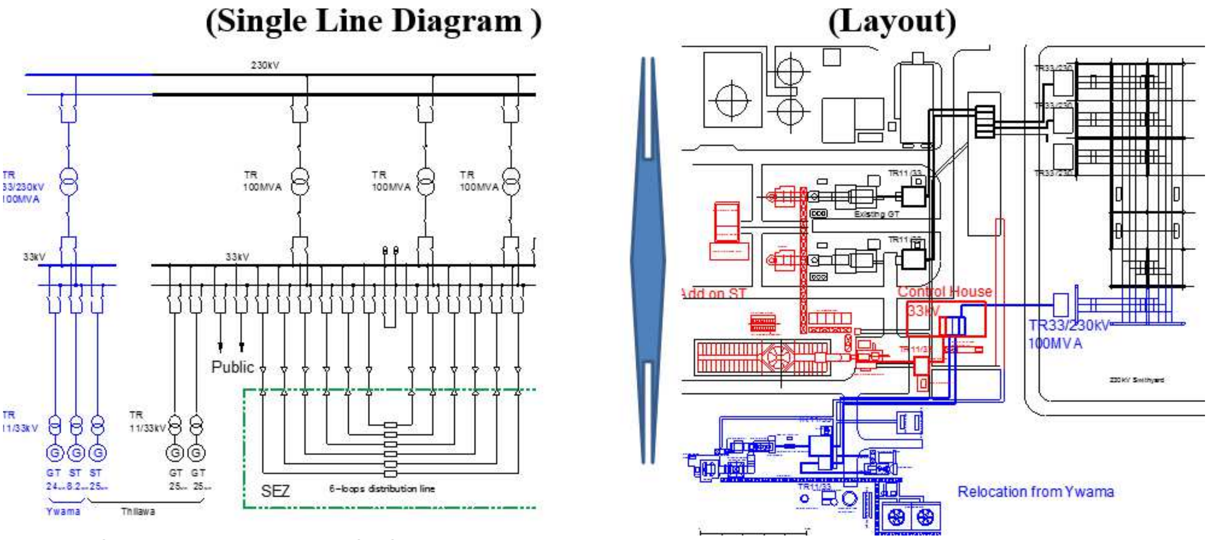
အဆိုပါ သီလဝါ ဓာတ်အားပေး စက်ရုံတွင် သုံးမည့် TG Connection နည်းလမ်းသည် လျှပ်စီး ပတ်လမ်းတို ပြဿနာ ကဲ့သို့သော ပြဿနာအားလုံးနီးပါကို ကျော်လွှားနိုင်မည်ဟု ယူဆရသည်။



Source: Prepared by the JICA Study Team

ပုံ ES၃.၄-၄ သီလဝါဓာတ်အားပေးစက်ရုံအတွက် ထောက်ခံအကြံပြုထားသော TG Connection Method

အဆိုပါ ထောက်ခံအကြံပြုထားသော connection method ၏ Single line diagram နှင့် Layout အား ပုံ ES3.4-5 ကဲ့သို့ ကိုးကားနိုင်ရန် ထပ်မံ ဖော်ပြထားသည်။



Source: Prepared by the JICA Study Team

ပုံ ES၃.၄-၅ ထောက်ခံအကြံပြုထားသော connection method ၏ Single line diagram နှင့် Layout

၃.၅ မြို့ပြနှင့် အဆောက်အဦး လုပ်ငန်းများ

သီလဝါ ထပ်ပေါင်း စီမံကိန်း နှင့် ရွာမ ပြန်လည်နေရာချထားရေး စီမံကိန်းများသည် တူညီသောအဆိုနှင့် ပြုလုပ်မည်ဆိုကတည်းက၊ မြို့ပြအင်ဂျင်နီယာဆိုင်ရာ ဆောက်လုပ်ရေး နှင့် ပက်သက်ပြီး တည်ရှိပြီးသားအခြေအနေကို စဉ်းစားရန် အရေးကြီး၍၊ ယင်း စီမံကိန်း ၂ ခုကို ပူးပေါင်းဆောင်ရွက်စီစဉ်ရမည်။

မြို့ပြအင်ဂျင်နီယာလုပ်ငန်းအတွက် လက်ရှိတည်ရှိနေသော simple cycle ဓာတ်အားထုတ်လွှတ်သော စက်ကရိယာအား အပြည့်အဂအသုံးချတည်ဆောက်သော အတွေ့အကြုံကို ထိရောက်အောင်စီစဉ်ရမည်ဖြစ်သည်။

ထို့အပြင်၊ အဆောက်အဦးအသစ်များတည်ဆောက်မှုပြင်ဆင်ခြင်းနှင့် လက်ရှိတည်ရှိနေသော အဆောက်အဦးများအသုံးပြုသောအခါ ပူးပေါင်းဆောင်ရွက်သောအစီအစဉ်တစ်ခုအား စီမံကိန်း ၂ ခုအဖြစ် ရေးဆွဲရန် လိုအပ်ပါသည်။

မြို့ပြအင်ဂျင်နီယာဆောက်လုပ်ခြင်းလုပ်ငန်း၏ အဓိက မာတိကာများအား အောက်ပါတွင်ဖော်ပြထားပါသည်

- အဆောက်အဦး အုတ်မြစ် နှင့် စက်ကိရိယာအတွက် အုတ်မြစ်တပ်ဆင်ခြင်း
- အုတ်မြစ်များအား သံကူကွန်ကရီ pile များဖြင့်ပြုလုပ်ထားသည်
- လျှပ်စစ်ထိန်းချုပ်သောအဆောက်အဦး တည်ဆောက်ခြင်း
- Hydraulic pile ရိုက်စက်ဖြင့် pile ရိုက်ခြင်း (Vibration free နည်းပညာဖြင့်)
- လက်ရှိနယ်နိမိတ်နံရံ တိုးချဲ့ခြင်း (လိုအပ်လျှင်)
- Cable ကြိုး နှင့် ပိုက်ထည့်ရန် ကျင်းတပ်ဆင်ခြင်း
- Cable ကြိုးထည့်ရန် မြောင်းတပ်ဆင်ခြင်း
- ပြုပြင်ထိန်းသိမ်းရမည့် ဧရိယာမျက်နှာပြင်များတွင် ကွန်ကရီခင်းခြင်း
- ကျောက်စရစ်ခင်းခြင်း

နှင့် အခြား မြို့ပြဆိုင်ရာ အဆောက်အဦးလုပ်ငန်းများ လိုအပ်ပါသည်။

အခန်း (၄) စီမံကိန်း အတွက် ကုန်ကျစရိတ်ခန့်မှန်းခြင်း နှင့် အကောင်အထည်ဖော်ရေးအတွက် ဇယား

၄.၁ စီမံကိန်း ကုန်ကျစရိတ်ခန့်မှန်းခြင်း

ခန့်မှန်းထားသော ကုန်ကျစရိတ်မှာ အောက်ပါအတိုင်းဖြစ်သည်-

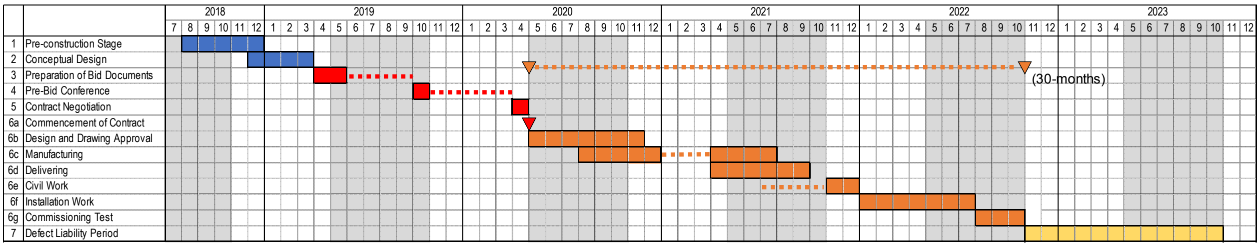
- ထပ်တိုးစီမံကိန်း ၏ ခန့်မှန်းကုန်ကျစရိတ် - ***
- နေရာပြောင်းရွှေ့စီမံကိန်း၏ ခန့်မှန်းကုန်ကျစရိတ် - ***

ဖော်ပြပါ ခန့်မှန်းကုန်ကျစရိတ်များသည် သင့်တော်သော EIA (Energy Information Administration) ကုန်ကျစရိတ် အချက်အလက်များ နှင့် ပုံနှိပ်ထုတ်ဝေထားသော အမှန်တယ်စီမံကိန်း ကုန်ကျစရိတ် အချက်အလက်များကို (ဥပမာ - စီမံကိန်းပိုင်ရှင်မှ ထုတ်ဝေထားသော) အခြေခံထားခြင်းဖြစ်သည်။

၄.၂ အချိန်ဇယား အကောင်အထည်ဖော်ခြင်း

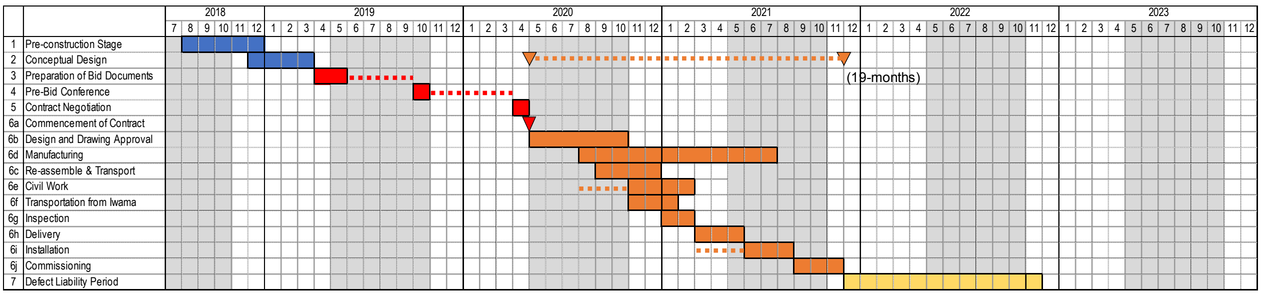
ခန့်မှန်းထားသော အချိန်ဇယားမှာ အောက်ပါအတိုင်း ဖြစ်သည်-

- ထပ်တိုးစီမံကိန်း ၏ ခန့်မှန်း အချိန်ဇယား - ၃၀ လ
- နေရာပြောင်းရွှေ့စီမံကိန်း၏ ခန့်မှန်း အချိန်ဇယား - ၂၄ လ



Source: Prepared by the JICA Study Team

ပုံ ES၄.၂-၁ သီလဝါ ထပ်တိုးအကောင်အထည်ဖော်ရေး အချိန်ဇယား



Source: Prepared by the JICA Study Team

ပုံ ES၄.၂-၂ ရွာမ နေရာပြောင်းရွှေ့ခြင်း အကောင်အထည်ဖော်ရေး အချိန်ဇယား

အခန်း (၅) ပတ်ဝန်းကျင် ထိန်းသိမ်းရေး နှင့် လူမှုရေး အခန်းကဏ္ဍအပေါ် စဉ်းစားခြင်း

ဤအခန်းတွင် -၁) မြန်မာနိုင်ငံ၏ ပတ်ဝန်းကျင် ထိန်းသိမ်းရေး နှင့် လူမှုရေးဆိုင်ရာ ဥပဒေနှင့်စည်းမျဉ်းများ။ ၂) စီမံကိန်းအနီး ပတ်ဝန်းကျင် ထိန်းသိမ်းရေး နှင့် လူမှုရေးဆိုင်ရာ အခြေခံ အခြေအနေများ။ ၃) စီမံကိန်း အကောင်အထည်ဖော်ရန် အတွက် ပတ်ဝန်းကျင် ထိန်းသိမ်းရေး နှင့် လူမှုရေး အခန်းကဏ္ဍအပေါ် စဉ်းစားခြင်း။ ၄) လက်ရှိ GTG စီမံကိန်း၏ သဘာဝပတ်ဝန်းကျင် စွမ်းဆောင်ရည်။ ၅) စီမံကိန်း အကောင်အထည်ဖော်ရေးကို မြန်မာနိုင်ငံဘက်မှ ပိုင်းခြားသတ်မှတ်မှု။ ၆) တိုးပွားလာသော အကျိုးသက်ရောက်မှုကို အကဲဖြတ်မှု။ ၇) ပြဿနာများကို ဖြေရှင်းခံရဖို့ နှင့် စီမံကိန်း၏ထောက်ခံချက်များကို ဖော်ပြထားသည်

၅.၁ စီမံကိန်း၏ ရွေးချယ်ပိုင်ခွင့်

အောက်ဖော်ပြပါ ရွေးချယ်ပိုင်ခွင့်များသည် ၁) နည်းပညာ ၂) ဘဏ္ဍာရေး နှင့် စီးပွားရေး ၃) ပတ်ဝန်းကျင်ဆိုင်ရာရှုထောင့် ဖော်ပြပါ ဇယား ES၅.၁-၁ တို့ဖြင့် နှိုင်းယှဉ်အကဲဖြတ် ထားသည်။

ဇယား ES၅.၁-၁ ရွေးချယ်စရာအချက်များ နှိုင်းယှဉ်ခြင်း

အချက်အလက်	ရွေးချယ်ခွင့် ၁	ရွေးချယ်ခွင့် ၂	ရွေးချယ်ခွင့် ၃	ရွေးချယ်ခွင့် ၄
ဝိသေသလက္ခဏာများ Characteristics	လက်ရှိ GT ၂လုံး၏ combined cycle	ရွာမမှ NEDO Unit (1GT+1ST) နေရာရွှေ့ခြင်း	ရွာမ မှ NEDO Unit/ Combined cycle of 3 GTs နေရာချထားခြင်း နှင့် ပြန်လည်ထူထောင်ခြင်း	ရွေးချယ်ခွင့် ၁+၂
စက်ရုံ ဖွဲ့စည်းမှု Composition of Plant (GT:G:STG)	၂:၂:၁	၂:၂ (တည်ရှိပြီး) ၁:၁:၁	၃:၃:၁	၂:၂:၁ + ၁:၁:၁
အပိုစွမ်းဆောင်ရည် Additional Capacity (MW)	၂၅	၃၂.၂	၂၃.၂+၃၆.၆=၅၉.၈	၂၅+၃၂.၂=၅၇.၂
စုစုပေါင်း စီစဉ်ထားသော စွမ်းဆောင်ရည် Total Planned Capacity (MW)	၇၅ (တည်ရှိပြီး ၅၀, အသစ် ၂၅)	၈၂.၂ (၅၀+၃၂.၂)	၁၀၉.၈ (၅၀+၅၉.၈)	၁၀၇.၂ (၅၀+၅၇.၂)
ACC နှင့် WCC အအေးခံ နည်းဖြင့် ရေသုံးစွဲမှု ခန့်မှန်းချက် (ton/day)	၂၅၀ (ACC) ၃၃၄၀ (WCC)	၈၃ (ACC) ၁၁၀၄ (WCC)	၃၇၅ (ACC) ၅၀၁၀ (WCC)	၃၃၃ (ACC) ၄၄၄၄ (WCC)
ပတ်ဝန်းကျင် (လေထု) Environment (air)	လက်ရှိ GT ၂လုံးမှ ထုတ်လွှတ်သော ဓာတ်ငွေ့သည် သတ်မှတ် အဆင့်ကို လိုက်နာသည်။	လက်ရှိ GT ၂လုံး နှင့် ရွာမ မှရွှေ့လာမည့် ပြန်လည်ပြင်ဆင်ထားသော GT & ST ၁လုံးတို့မှ စုပေါင်းဓာတ်ငွေ့ သည် ထုတ်လွှတ်ရန် သတ်မှတ်ထားသော အဆင့်ကို လိုက်နာမှု ရှိ ၊ မရှိ စစ်ဆေးရန် လိုအပ်သည်။		
ပတ်ဝန်းကျင် (ရေအသုံးပြုမှု နှင့် မြေကျွံမှု) Environment (water use and ground subsidence)	မြေအောက်ရေ အရင်းအမြစ် ပြတ်လတ်မှုကြောင့် နှင့် မြေကျွံမှုကို ရှောင်ရှားရန် အတွက် မြေအောက်ရေ ရယူရန် ခက်ခဲသည်။ မြေပေါ်ရေယူရန် လိုအပ်သည်။ (ဥပမာ - ရေလှောင်ကန် ၊ မြစ်ရေ)			
လူမှုရေး (Social)	ပြန်လည် နေရာချထားမှု မရှိခြင်း၊ မြေယာ သိမ်းပိုက်ခြင်း နှင့် ဝင်ငွေပြန်လည်ထူထောင်ခြင်း။		စီမံကိန်း အတွက်အသုံးပြုရန် စီစဉ်ထား သော လက်ရှိတည်ရှိနေသော မြေတွင် ပြန်လည် နေရာချထားမှု မရှိခြင်း၊ မြေယာသိမ်းပိုက်ခြင်းနှင့်ဝင်ငွေပြန်လည်ထူထောင်ခြင်း။ (စီမံကိန်းအနီး ယာယီဆောက်လုပ်ရေးအတွက် ပြုလုပ်ရာတွင်သီးနှံလျော်ကြေး ကဲ့သို့ ဝင်ငွေပြန်လည်ထူထောင်ခြင်းကို ကူညီရန် အိမ်ထောင်စု ၁စု သို့မဟုတ် ၂စု လိုအပ်နိုင်သည်။)	

Source: Prepared by the JICA Study Team

၅.၂ အဆိုပြုစီမံကိန်း အကောင်အထည်ဖော်ရန် အတွက် EIA ခွင့်ပြုချက် လုပ်ငန်းစဉ်

စီမံကိန်း အဆင့်မြှင့်တင်မှုအတွက် EIA လေ့လာရေး မွမ်းမံခြင်း၏ မျှော်မှန်း ကာလ ကို **ဇယား ES၅.၂-၁** တွင် ဖော်ပြထားသည်။ အမျိုးသား ပတ်ဝန်းကျင်ထိန်းသိမ်းရေးနှင့် ရာသီဥတုပြောင်းလဲမှု ဗဟိုကော်မတီ (NECCCCC) ပေါ်ပေါက်ပြီးနောက် မူကြမ်း EIA အစီရင်ခံစာ မွမ်းမံပြင်ဆင်မှု မှ MPNREC မှ ခွင့်ပြုသည့် EIA အစီရင်ခံစာ ရသည် အထိကို စုစုပေါင်း ၁၂.၅ လခန့် ကြာမြင့်ပါသည်။

ဇယား ES၅.၂-၁ အဆိုပြုထားသော EIA လေ့လာရေးအတွက် မျှော်မှန်းအချိန်ဇယား

စဉ်	လုပ်ဆောင်ချက်များ၏ဖော်ပြချက်	မျှော်လင့်သော/ လိုအပ်သော အချိန်ကာလ	မှတ်ချက်
၀	Completion of F/S Report ဖြစ်နိုင်ချေရှိသော လေ့လာမှု အစီရင်ခံစာ ပြီးစီးခြင်း		
၁	EIA အစီရင်ခံစာ အကြမ်း မွမ်းမံမှု အတွက် ပြင်ဆင်ခြင်း	၂ လ	
၂	EIA အစီရင်ခံစာ အပြီးသတ်ခြင်း၊ ထုတ်ဖော်ခြင်း နှင့် အများပြည်သူ အကြံပေးခြင်းတို့ အတွက် စီစဉ်ခြင်း	၂ လ	
၃	နောက်ဆုံး EIA အစီရင်ခံစာ တင်ပြ ခြင်း နှင့် အကဲဖြတ်ခြင်း	၄.၅ လ	*MOEE's cover letter on request of urgent review shall be required. အရေးပေါ် သုံးသပ်ချက် တောင်းဆိုရန် MOEE ၏ cover letter လိုအပ်သည်။
၄	NECCCCC မှ ခွင့်ပြုခြင်း	၄ လ	- အမျိုးသားပတ်ဝန်းကျင်ထိန်းသိမ်းရေး နှင့် ရာသီဥတုပြောင်းလဲရေး ကော်မတီ - ကော်မတီအစည်းအဝေးကို ၄လတိုင်း ပြုလုပ်မည်။

Source: Prepared by the JICA Study Team

၅.၃ မြန်မာနိုင်ငံဘက်မှ လုပ်ဆောင်ချက် နှင့် လုပ်ရှားမှုများ

သီလဝါ ဓာတ်အားပေးစက်ရုံ အဆင့်မြှင့်တင်မှု စီမံကိန်း စတင်သောအခါ အောက်ပါ ဇယား **Table ES5.3-1** ဖော်ပြပါ လုပ်ဆောင်ချက်နှင့် လှုပ်ရှားမှုများကို မြန်မာ ဘက်မှ လုပ်ဆောင်သင့်သည်။ (ဥပမာ MOEE / EPGE)

ဇယား ES၅.၃-၁ MOEE နှင့် EPGE တို့၏လိုအပ်သော လှုပ်ရှားမှုများ

စဉ်	လုပ်ဆောင်ချက်များ	မှတ်ချက်
1.	မြေယာလျော်ကြေး၊ နေရာပြန်လည်ချထားခြင်း၊ ငွေကြေးပြန်လည်ထူထောင်ခြင်း၊ သီးနှံလျော်ကြေး	TSMC မှ MOEE သို့ လက်ရှိ ၁၀ ha စီမံကိန်းဧရိယာ အသုံးပြုခွင့် ပေးအပ် (ဓာတ်အားပေးစက်ရုံ နှင့် ဓာတ်အားခွဲရုံ)။ နောင်မြေယာ တိုးချဲ့ခြင်း အတွက် TSMC နှင့် MOEE တို့ အတူပူပေါင်းလုပ်ရှား ရမည်။
2.	ရေပေးဝေရေး စနစ်နှင့် ရေလှောင်ကန် စသော ရေအသုံးပြုမှုအတွက် သက်ဆိုင်ရာ အာဏာပိုင်များနှင့် ညှိနှိုင်းဆွေးနွေးရန်။	
3.	အစုရှယ်ယာပါဝင်သူများ အစည်းအဝေး၊ EIA လေ့လာရေးတွင်ပါဝင်သည့် လူထုအကြံပေး အစည်းအဝေးများ တက်ရောက်ရန်။	
4.	စီမံကိန်း အဆင့်မြှင့်တင်ရေးအတွက် လိုအပ်သော သက်ဆိုင်ရာ ပတ်ဝန်းကျင် အချက်အလက်များကို ထောက်ပံ့ပေးရန်	
5.	စက်ရုံလည်ပတ်နေစဉ် နှင့် ပြုပြင်နေစဉ် အတွင်း ပတ်ဝန်းကျင် ဆိုင်ရာ စောင့်ကြည့်စစ်ဆေးခြင်း နှင့် စီမံဆောင်ရွက်ခြင်း ကို ညွှန်ကြားဆောင်ရွက်ရန်	
6.	ဆောက်လုပ်ရန်တားမြစ်ထားသော မြေလွတ်များရရှိခဲ့လျှင် ထိုမြေကို သစ်ပင်များ အသီးအနှံပင်များ နှင့် ဖုံးလွှမ်းအောင် ပြုလုပ်ရန်	

Source: Prepared by the JICA Study Team

၅.၄ ပြဿနာဖြေရှင်းရန် နှင့် စီမံကိန်း၏ထောက်ခံချက်

၁) EIA လေ့လာမှု အကောင်အထည်ဖော်ရန် ကူညီမှု

အထက်ဖော်ပြပါအတိုင်း EIA လေ့လာမှုသည် စတင်ပြင်ဆင်ချိန်မှ အပြီးသတ်အစီရင်ခံစာအထိကို ၁နှစ် နီးပါးကြာမြင့်ပါသည်။ အဆိုပါ တရားဝင်အတည်ပြုထားသော ဓာတ်ငွေ့ထုတ်လွှတ်မှု နှင့် MONREC ECD မှ ဆုညံမှု စံနှုန်းတို့ ပါဝင်သော EIA ခွင့်ပြုကို ကန်ထရိုက်တာများဆီသို့ တင်ဒါစာရွက်စာတမ်းများ မဖြန့်ဝေမီ အချိန်ကို လိုအပ်ပါသည်။ အသေးစိတ် ဒီဇိုင်း သို့မဟုတ် ယန်းချေးငွေ လေလံမဆွဲခင် EIA အစီရင်ခံစာ ပြုပြင်မွမ်းမံမှု စတင်ပြင်ဆင်ရန် လိုအပ်ပါသည်။ MOEE မှ JICA သို့ EIA အစီရင်ခံစာ ပြုပြင်မွမ်းမံမှု တွင် အထောက်အပံ့ပေးရန် တောင်းဆိုသောကြောင့် လိုအပ်ခဲ့လျှင် EIA လေ့လာရေးအတွက် အတိုင်ပင်ခံ ပြင်ဆင်ရေးနှင့် လုပ်ဆောင်ရေး အချိန်ကိုက်လုပ်ဆောင်ရန် လိုအပ်ပါသည်။

၂) NOx ထုပ်လွှတ်မှု စံနှုန်း၏လျှော့ကျလွှာ

ဤအဆင့်မြှင့်တင်သည့်စီမံကိန်းတွင် ရွာမဓာတ်အားပေးစက်ရုံမှ ဓာတ်ငွေ့တာဘိုင်တွင် NOxလျော့ချရန် ရေဆေးထိုးသည့်စနစ် (water injection system) မပါရှိပေ။ ထို့ကြောင့် ထိုဓာတ်ငွေ့တာဘိုင်မှ Nox အဆင့်ကို

ရေဆေးထိုးသည့်စနစ် (water injection system) မရှိသော သီလဝါဓာတ်အားပေး စက်ရုံကဲ့သို့ ၆၀ppm မှ ၁၁၀ppm အထိ မျှော်မှန်းထားသည်။ ရေဆေးထိုးသည့်စနစ် (water injection system) ဖြင့် NOx စောင့်ကြည့်ထားသော အချက်သည် ၂၅ppm ဝန်းကျင်ရှိသော အချက်ကို အခြေခံ၍ သီလဝါဓာတ်အားပေးစက်ရုံ၏ NOx ပျမ်းမျှအဆင့်သည် ရေဆေးထိုးသည့်စနစ် (water injection system) မရှိဘဲ ၉၇ ppm အောက်နဲမည်ဟု အတည်ပြုလိမ့်မည်။ NEQG NOx ထုတ်လွှတ်မှု ခွင့်ပြုခြင်းဖြင့် ပျမ်းမျှ NOx အဆင့်သည် ၄၉ppm ရှိလိမ့်မည်။ (သီလဝါတွင် ဓာတ်ငွေ့တာဘိုင် တစ်ခုစီမှ ၂၅ ppm နှင့် ရွာမ ဓာတ်ငွေ့တာဘိုင်မှ ၉၇ ppm)

NEQG သည် ဓာတ်ငွေ့တာဘိုင်တစ်ခုစီမှ ထုတ်လွှတ်မည့် NOx စံနှုန်း နှင့် ဓာတ်ငွေ့တာဘိုင်အားလုံးစီမှ ပျမ်းမျှ ထုတ်လွှတ်မည့် NOx စံနှုန်း လျှောက်လွှာ ကဲ့သို့ အသေးစိတ်ရှင်းလင်းစွာပါရှိသော လျှောက်လွှာကို မဖော်ပြထားပါ။ (ပျမ်းမျှခြင်းကို ယူနစ်သုံးခုမှ စုစုပေါင်း လေထုညစ်ညမ်းမှုဂန် ကို ဓာတ်အားထုတ်လွှတ်မှုစုစုပေါင်း နှင့်စားခြင်းဖြင့် တွက်ထုတ်သည်။ လေထုညစ်ညမ်းမှုဂန်ကို ထုတ်လွှတ်သည့် ဓာတ်ငွေ့ထုထည် နှင့် တစ်ယူနစ်ခြင်းစီမှ ထုတ်လွှတ်သည့်ဓာတ်ငွေ့စုစည်းမှု တို့မြှောက်ခြင်းဖြင့်ရရှိသည်။ စုစုပေါင်းလေထုညစ်ညမ်းမှုဂန်သည် တစ်ယူနစ်ခြင်းစီမှ လေထုညစ်ညမ်းမှုဂန်ကို ပေါင်းထားခြင်း ဖြစ်သည်။) ထို့ကြောင့် နောက်ဆုံးမွမ်းမံပြီးတဲ့ EIA အစီရင်ခံစာ ဆွေးနွေးမှု နှင့် အကဲဖြတ်လုပ်ငန်းစဉ် မှတစ်ဆင့် MONREC ECD ၏ အထက်ဖော်ပြပါ စံနှုန်းလျှောက်လွှာ ခွင့်ပြုရန် လိုအပ်သည်။

၃) လက်ရှိသီလဝါ ဓာတ်အားပေးစက်ရုံတွင် NOx ဓာတ်ငွေ့ထုတ်လွှတ်မှုလျှော့ချရန်အတွက် ရေဆေးထိုးသည့်စနစ် (water injection system) ၏ လျှောက်လွှာများအား စောင့်ကြည့်လေ့လာရေး

အထက်ဖော်ပြပါအတိုင်း လက်ရှိ သီလဝါဓာတ်အားပေးစက်ရုံ(25MW x 2 units) တွင် NOx ထုတ်လွှတ်မှုလျှော့ချရန် အတွက် ရေဆေးထိုးသည့်စနစ် (water injection system) ပါရှိသည်။ သို့သော် ရေဆေးထိုးသည့်စနစ် (water injection system) သည် ယန်းချေးငွေစီမံကိန်းဖြစ်သော ရန်ကုန်ရေထောက်ပံ့မှု (Phase 1) အောက်ရှိ လဂွန်းပြင် ရေလှောင်ကန်မှ ရေထောက်ပံ့မှုရရှိပြီးနောက်မှ စတင်လိမ့်မည်။ ရေဆေးထိုးသည့်စနစ် (water injection system) အတွက် ရေထောက်ပံ့မှု သည် NEQG တွင်စည်းကမ်းချမှတ်ထားသော NOx ထုတ်လွှတ်စုစည်းမှု နှင့်ကိုက်ညီရန် စီမံကိန်းအတွက် လိုအပ်သော အချက်ဖြစ်သည်။ ဒ့်အပြင် လက်ရှိသီလဝါ ဓာတ်အားပေးစက်ရုံအတွက် ရေဆေးထိုးသည့်စနစ် (water injection system) ၏စောင့်ကြည့်လျှောက်လွှာများလည်း လိုအပ်သည်။

အခန်း (၆) ဘဏ္ဍာရေးနှင့် စီးပွားရေး ရှင်သန်နိုင်စွမ်း

၆.၁ စီမံကိန်းမှ ခန့်မှန်းထားသည့် သက်ရောက်မှု (လုပ်ငန်းလည်ပတ်မှု နှင့် အကျိုးသက်ရောက်မှု ညွှန်းကိန်းများ)

လုပ်ငန်းလည်ပတ်မှု ညွှန်းကိန်းများသည် စီမံကိန်းစနစ်တကျ လည်ပတ်လျက်ရှိ/မရှိ ရေတွက်စစ်ဆေး၍ စီမံကိန်းများ၏ လုပ်ငန်းလည်ပတ်မှု အခြေအနေကို အကဲဖြတ်ရန် ရည်ရွယ်သည်။

ဇယား ES ၆.၁-၁ လုပ်ငန်းလည်ပတ်မှု ညွှန်းကိန်း များ (နည်းလမ်း ၁)

ညွှန်းကိန်း	တွက်ချက်ပုံ	ရည်မှန်းချက်
စက်ရုံ၏ဝန်ကိန်း (Plant load factor) (%)	=တစ်နှစ်တွင်ထုတ်လုပ်သောလျှပ်စစ်/ (သတ်မှတ်ထွက်နှုန်း x တစ်နှစ်ရှိ နာရီပေါင်း) x ၁၀၀ = Electricity generated per year /(rated output × hours per year) ×100	၈၀%
အပူနှင့်ဆိုင်သောသာရည်စုစုပေါင်း (Gross thermal efficiency)	=(တစ်နှစ်တွင်ထုတ်လုပ်သောလျှပ်စစ်စုစုပေါင်း x ၈၆၀)/ (တစ်နှစ်တာ လောင်စာဆီသုံးစွဲမှု x လောင်စာဆီကြောင့်ထွက်လာသောအပူ)x ၁၀၀ = (Gross electricity generated per year × 860) / (fuel consumption per year × heat release value of the fuel) × 100	၄၅% အထက်

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

ဇယား ES ၆.၁-၂ လုပ်ငန်းလည်ပတ်မှု ညွှန်းကိန်း များ (နည်းလမ်း ၂)

ညွှန်းကိန်း	တွက်ချက်ပုံ	ရည်မှန်းချက်
စက်ရုံ၏ဝန်ကိန်း (Plant load factor) (%)	=တစ်နှစ်တွင်ထုတ်လုပ်သောလျှပ်စစ်/ (သတ်မှတ်ထွက်နှုန်း x တစ်နှစ်ရှိ နာရီပေါင်း) x ၁၀၀ = Electricity generated per year /(rated output × hours per year) ×100	၈၀%
အပူနှင့်ဆိုင်သောသာရည်စုစုပေါင်း (Gross thermal efficiency)	=(တစ်နှစ်တွင်ထုတ်လုပ်သောလျှပ်စစ်စုစုပေါင်းx၈၆၀)/(တစ်နှစ်တာ လောင်စာဆီသုံးစွဲမှု x လောင်စာဆီကြောင့်ထွက်လာသောအပူ)x၁၀၀ = (Gross electricity generated per year × 860) / (fuel consumption per year × heat release value of the fuel) × 100	၄၃%

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

အကျိုးသက်ရောက်မှုညွှန်းကိန်းများသည် စီမံကိန်းမှ ပေါ်ထွက်လာသော ရလဒ်ကို အကဲဖြတ်ရန် ရည်ရွယ်သည်။

ဇယား ES ၆.၁-၃ အကျိုးသက်ရောက်မှု ညွှန်းကိန်းများ (နည်းလမ်း ၁)

ညွှန်းကိန်း	တွက်ချက်ပုံ	ရည်မှန်းချက်
အသားတင် လျှပ်စစ်စွမ်းအင် ထုတ်လုပ်မှု (Net electric energy production) (GWh)	ညွှန်းကိန်းအမည်ဖြင့်ဖော်ပြထားသည်	၁၇၅.၂ GWh
အများဆုံး အထုတ် (Maximum output) (MW)	ညွှန်းကိန်းအမည်ဖြင့်ဖော်ပြထားသည်	၂၅ MW

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

ဇယား ES ၆.၁-၄ အကျိုးသက်ရောက်မှု ညွှန်းကိန်းများ (နည်းလမ်း ၂)

ညွှန်းကိန်း	တွက်ချက်ပုံ	ရည်မှန်းချက်
အသားတင် လျှပ်စစ်စွမ်းအင် ထုတ်လုပ်မှု (Net electric energy production) (GWh)	ညွှန်းကိန်းအမည်ဖြင့်ဖော်ပြထားသည်	၂၂၅.၇ GWh
အများဆုံး အထုတ် (Maximum output) (MW)	ညွှန်းကိန်းအမည်ဖြင့်ဖော်ပြထားသည်	၃၂.၂ MW

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

၆.၂ ဘဏ္ဍာရေးနှင့် စီးပွားရေး အားသုံးသပ်ခြင်း

၆.၂.၁ ဘဏ္ဍာရေး ခွဲခြမ်းစိတ်ဖြာခြင်း နှင့်စီးပွားရေး ဆန်းစစ်ခြင်းများ ၏ ရည်ရွယ်ချက်များနှင့် နည်းလမ်းများ

ဘဏ္ဍာရေးနှင့် စီးပွားရေးဆန်းစစ်ခြင်းများသည် စီမံကိန်းများ၏ ရှင်သန်နိုင်စွမ်း ဆန်းစစ်ရန် ရည်ရွယ်ထားပြီး IRR (Internal Rate of Return) နှင့် NPV (Net Present Value) တို့ကို တွက်ချက်ခြင်းဖြစ်ကာ ရွေးချယ်ထားသော နည်းလမ်းများ အတွက်ဆောင်ရွက်ခြင်းဖြစ်သည်။

ဘဏ္ဍာရေးခွဲခြမ်းစိတ်ဖြာမှုကို စီမံကိန်းအကောင်အထည်ဖော်မည့်အဖွဲ့အစည်း (EPGE-လျှပ်စစ်ဓာတ်အားထုတ်လုပ်ရေးလုပ်ငန်း) ၏ရှုထောင့်မှနေ၍ စီမံကိန်း၏ အကျိုးဖြစ်ထွန်းမှုကို အကဲဖြတ်ရန် ဆောင်ရွက်သည်။ FIRR (Financial Internal Rate of Return) နှင့် FNPV (Financial Net Present Value) တို့ကိုရရှိရန်အတွက်၊ စီမံကိန်း၏ အသားတင်အကျိုးခံစားခွင့်ကို စဉ်းစားတွက်ချက်ရာတွင် ၁) အကျိုးကျေးဇူးများ -ဥပမာ အဆိုပါစီမံကိန်းအနေဖြင့် အကောက်အခွန်မှ တိုးလာသောဝင်ငွေ၊ ၂) ဈေးကွက်ပေါက်ဈေး အပေါ်အခြေခံသော ကုန်ကျစရိတ် တို့ဖြစ်သည်။

စီးပွားရေးဆန်းစစ်မှုကို နိုင်ငံ၏စီးပွားရေး ရှုထောင့်မှနေ၍ စီမံကိန်းများ၏ ရှင်သန်နိုင်စွမ်းကို အကဲဖြတ်ဖို့ရန်ဆောင်ရွက်သည်။ EIRR (Economic Internal Rate of Return) နှင့် ENPV (Economic Net Present Value) တို့ကိုရရှိရန် အတွက်၊ စီမံကိန်း၏ အကျိုးခံစားခွင့်ကို စဉ်းစားတွက်ချက်ရာတွင် ၁) အခြားရွေးချယ်စရာစွမ်းအင်ရင်းမြစ်များ (ဥပမာ၊ ဒီဇယ်မီးစက်) ကိုအစားထိုးခြင်းအားဖြင့် သက်သာသွားသော စရိတ်ကြောင့် တိုးလာသော အကျိုးအမြတ်၊ ၂) စီးပွားရေးကုန်ကျစရိတ် တို့ဖြစ်သည်။

၆.၂.၂ ဘဏ္ဍာရေးသုံးသပ်ခြင်း

အကျိုးခံစားခွင့်များနှင့် ကုန်ကျစရိတ် ပြုစုခြင်း နှင့် တွက်ချက်ခြင်း တို့ကိုပြုလုပ်ရာတွင် ၂၀၁၇ ဈေးနှုန်းများကို ထည့်သွင်းစဉ်းစားကာ FIRR ရယူနိုင်ရန်အတွက် ဖြစ်သည်။ ထို့အပြင် ငွေတိုက်စာချုပ် (၈.၈%) ၏နှုန်းကို FNPV တွက်ချက်မှုများ အတွက် လျှော့ဈေးနှုန်းအဖြစ် အသုံးပြုပါသည်။ အဆိုပါ လျှော့ဈေးနှုန်းကို အသုံးပြုခြင်းအားဖြင့် နည်းလမ်း ၁ ၏ FNPV ကို အပေါင်းတန်ဖိုး သို့ပြောင်းစေ၍၊ နည်းလမ်း ၂ တွင်မူ ဓာတ်ငွေ့ကုန်ကျစရိတ် နှင့် တိုတောင်းသော စီမံကိန်းသက်တမ်း နှစ်၂၀ တို့ကြောင့် နည်းလမ်း ၂ တွင် အနှုတ်တန်ဖိုးဖြစ်လာသည်။

ဇယား ES ၆.၂-၁ FIRR နှင့် FNPV

	FIRR	FNPV (ကျပ် သန်းပေါင်း)	FNPV (အမေရိကန်ဒေါ်လာ သန်းပေါင်း)
နည်းလမ်း ၁	***	***	***
နည်းလမ်း ၂	***	***	***
စုစုပေါင်း	***	***	***

Source: Prepared by the JICA Study Team
Note: FIRR and FNPV of Total (Option 1+Option 2) are calculated based on 30 years of project life.

ဘဏ္ဍာရေးသုံးသပ်ရန် အတွက်ဆောင်ရွက်သော ခွဲခြမ်းစိတ်ဖြာမှု (Sensitivity Analysis) မှ အခြေခံအဖြစ်ယူဆသော အခြေအနေသည် အမှန်တကယ်အခြေအနေမှကွဲပြားခြားနားနိုင်ပါသည်။ ခွဲခြမ်းစိတ်ဖြာမှု (Sensitivity Analysis) တွင် ၁) ကုန်ကျစရိတ်တိုးမြင့်မှု (+ ၁၀%)၊ ၂) တည်ဆောက်မှုနှောင့်နှေးခြင်း (၁ နှစ်) တို့ကို ထည့်သွင်းစဉ်းစား ထားပါသည်။

ဇယား ES ၆.၂-၂ ဘဏ္ဍာရေးသုံးသပ်ရန် အတွက်ဆောင်ရွက်သော ခွဲခြမ်းစိတ်ဖြာမှု (နည်းလမ်း ၁)

အကြောင်းကိစ္စ	အကျိုးအမြတ်	ကုန်ကျစရိတ်	FIRR (%)	FNPV (ကျပ် သန်းပေါင်း)	FNPV (အမေရိကန်ဒေါ်လာ သန်းပေါင်း)
အခြေခံအခြေအနေ	မပြောင်း	မပြောင်း	***	***	***
ကုန်ကျစရိတ်တိုးမြင့်မှု (+၁၀%)	မပြောင်း	+၁၀%	***	***	***
တည်ဆောက်မှုနှောင့်နှေးခြင်း (၁နှစ်)	မပြောင်း	မပြောင်း	***	***	***

Source: Prepared by the JICA Study Team
Note: The cost includes both the financial cost during construction period and O&M cost.

ဇယား ES ၆.၂-၃ ဘဏ္ဍာရေးသုံးသပ်ရန် အတွက်ဆောင်ရွက်သော ခွဲခြမ်းစိတ်ဖြာမှု (နည်းလမ်း ၂)

အကြောင်းကိစ္စ	အကျိုးအမြတ်	ကုန်ကျစရိတ်	FIRR (%)	FNPV (ကျပ် သန်းပေါင်း)	FNPV (အမေရိကန်ဒေါ်လာ သန်းပေါင်း)
အခြေခံအခြေအနေ	မပြောင်း	မပြောင်း	***	***	***
ကုန်ကျစရိတ်တိုးမြင့်မှု (+၁၀%)	မပြောင်း	+၁၀%	***	***	***
တည်ဆောက်မှုနှောင့်နှေးခြင်း (၁နှစ်)	မပြောင်း	မပြောင်း	***	***	***

Source: Prepared by the JICA Study Team
Note: The cost includes both the financial cost during construction period and O&M cost.

နည်းလမ်း ၁ ၏ FNPV သည် အားလုံးသော ခွဲခြမ်းစိတ်ဖြာခြင်း (Sensitivity Analysis) ကိစ္စများတွင် အပြုသဘောဆောင်နေဆဲဖြစ်သည်။ အခြားတစ်ဖက်တွင် နည်းလမ်း ၂ ၏ FNPV သည် တိုးမြင့်လာသော ဓာတ်ငွေ့ကုန်ကျစရိတ် ၏ ထင်ဟပ်မှုကြောင့် ခွဲခြမ်းစိတ်ဖြာမှု (Sensitivity Analysis) အားလုံးတွင် အနှုတ်သဘောဆောင်ပြီး အမြတ်ကိုလည်းလျှော့ကျစေသည်။

၆.၂.၃ စီးပွားရေး သုံးသပ်ခြင်း

EIRR ရယူနိုင်ရန်အတွက် စီးပွားရေးအကျိုးအမြတ်နှင့် ကုန်ကျစရိတ်ပြုစုခြင်း၊ တွက်ချက်ခြင်းတို့တွင် ENPV ရရှိစေရေးအတွက် လူမှုရေး လျှော့နှုန်း (Social Discount Rate) မှာ (၁၂%) ဖြစ်သည်။

ဇယား ES ၆.၂-၄ EIRR နှင့် ENPV

	EIRR	ENPV (ကျပ် သန်းပေါင်း)	ENPV (အမေရိကန်ဒေါ်လာ သန်းပေါင်း)
နည်းလမ်း ၁	***	***	***
နည်းလမ်း ၂	***	***	***
စုစုပေါင်း	***	***	***

Source: Prepared by the JICA Study Team
Note: EIRR and ENPV of Total (Option 1+Option 2) are calculated based on 30 years of project life..

ခွဲခြမ်းစိတ်ဖြာမှု ရလဒ်များအရ နည်းလမ်း ၂ ခုစလုံး၏ EIRR များသည် ဖြတ်တောက်မှုနှုန်း (Cut-off Rate) ထက်မြင့်မားကြောင်း အခြေခံဖြစ်ရပ်တွင်တွေ့ရသည်။ စီမံကိန်း၏ ENPV သည် နည်းလမ်း နှစ်ခုစလုံးတွင် ကောင်းမွန်သောရလဒ်များကိုပြသည်။ အဆိုပါစီမံကိန်းသည် အမျိုးသားစီးပွားရေးကို တိုးတက်အောင် ဆောင်ရွက်သော ရှုထောင့်မှ ကြည့်လျှင် သင့်တော်သည်။

စီးပွားရေး ဆန်းစစ်လေ့လာရန် အတွက် ခွဲခြမ်းစိတ်ဖြာမှု (Sensitivity Analysis) ပြုလုပ်သောအခါ တည်ဆောက်မှုစရိတ်တိုးမြင့်ခြင်းနှင့် ဆောက်လုပ်မှု နှောင့်နှေးခြင်းတို့ကို ထည့်သွင်းစဉ်းစားထားသည်။

ဇယား ES ၆.၂-၅ စီးပွားရေးသုံးသပ်ရန် အတွက်ဆောင်ရွက်သော ခွဲခြမ်းစိတ်ဖြာမှု (နည်းလမ်း ၁)

အကြောင်းကိစ္စ	အကျိုးအမြတ်	ကုန်ကျစရိတ်	EIRR	ENPV	
			(%)	(ကျပ် သန်းပေါင်း)	(အမေရိကန်ဒေါ်လာ သန်းပေါင်း)
အခြေခံအခြေအနေ	မပြောင်း	မပြောင်း	***	***	***
ကုန်ကျစရိတ်တိုးမြင့်မှု (+၁၀%)	မပြောင်း	+၁၀%	***	***	***
တည်ဆောက်မှုနှောင့်နှေးခြင်း (၁နှစ်)	မပြောင်း	မပြောင်း	***	***	***

Source: Prepared by the JICA Study Team
Note: The cost includes both the economic cost during construction period and O&M cost.

ဇယား ES ၆.၂-၆ စီးပွားရေးသုံးသပ်ရန် အတွက်ဆောင်ရွက်သော ခွဲခြမ်းစိတ်ဖြာမှု (နည်းလမ်း ၂)

အကြောင်းကိစ္စ	အကျိုးအမြတ်	ကုန်ကျစရိတ်	EIRR	ENPV	
			(%)	(ကျပ် သန်းပေါင်း)	(အမေရိကန်ဒေါ်လာ သန်းပေါင်း)
အခြေခံအခြေအနေ	မပြောင်း	မပြောင်း	***	***	***
ကုန်ကျစရိတ်တိုးမြင့်မှု (+၁၀%)	မပြောင်း	+၁၀%	***	***	***
တည်ဆောက်မှုနှောင့်နှေးခြင်း (၁နှစ်)	မပြောင်း	မပြောင်း	***	***	***

Source: Prepared by the JICA Study Team
Note: The cost includes both the economic cost during construction period and O&M cost.

ဆောက်လုပ်ရေးအတွက် ကုန်ကျစရိတ်ပြောင်းလဲမှု နှင့် တည်ဆောက်မှု နှောင့်နှေးခြင်းတို့သည် EIRR နှင့် ENPV အပေါ်သက်ရောက်မှု ရှိပြီး EIRR နှင့် ENPV အနည်းငယ်ပြောင်းလဲမှု ရှိသည်။

အခန်း (၇) စီမံကိန်းအတွက် မြန်မာနိုင်ငံတော်အစိုးရအဖွဲ့၏ စွမ်းဆောင်ရည်

ဤအခန်းတွင် ၁) အကောင်အထည်ဖော်မည့်အဖွဲ့အစည်း အပေါ် ခြုံငုံသုံးသပ်ချက်၊ ၂) စီမံကိန်းအကောင်အထည်ဖော်ရေးအတွက် ဖွဲ့စည်းပုံ၊ ၃) စီမံကိန်းအကောင်အထည်ဖော်ရေးအတွက်

လျှပ်စစ်ဓာတ်အားထုတ်လုပ်ရေးလုပ်ငန်း(EPGE) ၏ စွမ်းဆောင်နိုင်မှု အပေါ်လေ့လာမှု၊ ၄) ဂျပန်နိုင်ငံတွင် သင်တန်းပေးမှုများကို ဖော်ပြထားသည်။

လက်ရှိ စွမ်းဆောင်နိုင်မှုနှင့် လုပ်ငန်းလည်ပတ်မှု အခြေအနေများကို ဆန်းစစ်၍ လေ့ကျင့်ရေးအစီအစဉ်တွင် ပါဝင်သင့်သော အကြောင်းအရာများကို အဆိုပြုထားပါသည်။

The Study
on
Proposal for Improvement of Electricity Supply
in
Thilawa Area
in
Myanmar

Final Report

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Chapter 1 General Background

1.1 Economic and Financial Situation in Myanmar

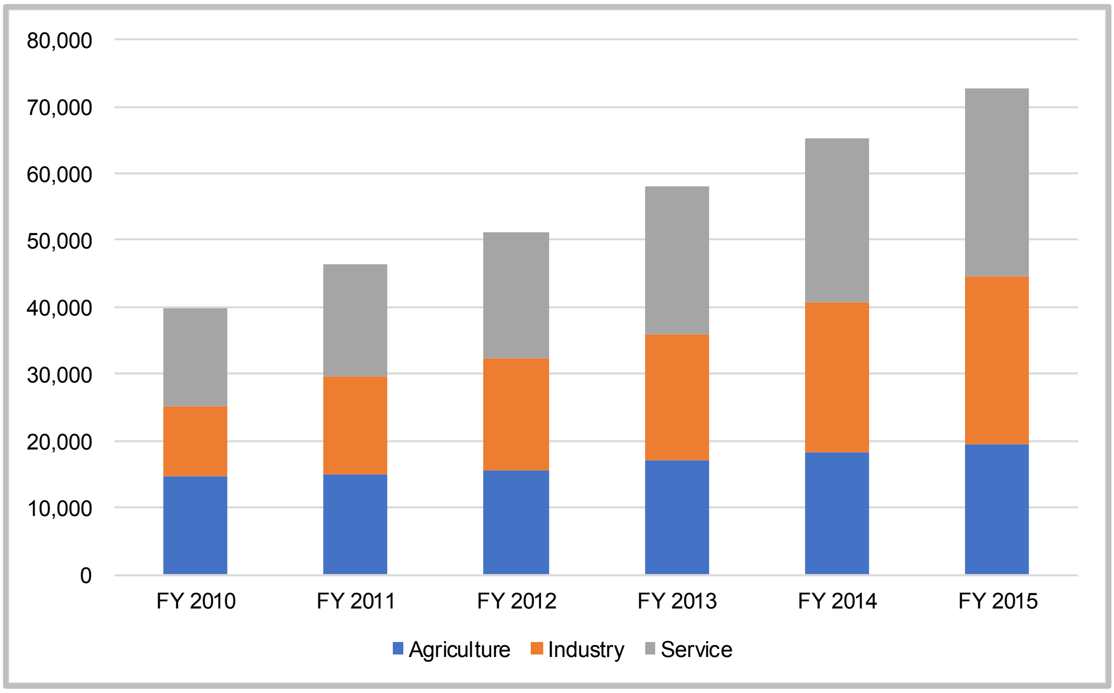
Myanmar has a population of 51.48 million in an area of 676,552.6 km^2. The population of Myanmar had increased by nearly 80% in the last 40 years.

Table 1.1-1 Trend of Population of Myanmar

	1973	1983	2014
Population (Mil.)	28,921	35,308	51,486
Change (%)		22.1%	45.8%

Source: Central Statistical Organization, "Statistical Yearbook 2016", Table 1.09 Population Proportion to the Union

The recent gross domestic product (GDP) of Myanmar achieved a steady growth of 10-15% per annum from FY 2011 to FY 2015.



(Unit: MMK in billion)

Source: Central Statistical Organization, "Statistical Yearbook 2016", Table 8.01 Gross Domestic Product (GDP) at Current Prices by Sectors of Activity

Figure 1.1-1 Gross Domestic Product (GDP) at Current Prices by Sector of Activity

Although the GDP of Myanmar has grown steadily, the sector-wise GDP shows a somewhat different picture. The industrial sector is a fast-growing sector, while the agriculture sector shows a low growth rate compared with other two sectors.

Table 1-1.2 Year to Year Percentage Change of GDP and Sector-wise GDP

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Agriculture	2.7%	4.2%	9.3%	6.0%	7.2%
Industry	37.6%	14.5%	13.1%	19.9%	11.7%
Service	14.9%	13.2%	16.4%	11.2%	14.6%
GDP	16.4%	10.7%	13.2%	12.5%	11.5%

Source: Central Statistical Organization, "Statistical Yearbook 2016", Table 8.01 Gross Domestic Product (GDP) at Current Prices by Sectors of Activity

According to the World Bank's report, the pace of economic growth has become moderate at 6.5% in FY 2016.[1] The report forecasts that the economic growth will be 7.1%/year in average in the next three years.

In line with the economic growth, per capita GDP has been increasing in recent years. Poverty has been decreasing between 2009 and 2015, according to the joint study by the World Bank and the Government of Myanmar.[2] However, poverty still remains substantial and is concentrated in rural areas. Approximately 70% of the poor people live in rural area.

Table 1.1-3 Per Capita GDP and Year to Year Percentage Change

(Unit: Myanmar Kyat)

	FY 2010	FY 2011	FY 2012
Per Capita GDP	801,418	923,406	1,011,689
Year to Year change		15.2%	9.6%

Source: Central Statistical Organization, "Statistical Yearbook 2016", Table 8.03 Expenditure on Gross Domestic Product at Constant Prices

The Government of Myanmar plays a major role in developing the environment to enable the country achieve economic growth and reduce poverty. The volume of the revenue and expenditure has been increasing but the budget deficit has been also increasing.

Table 1.1-4 Trend of the Government Budget

(Unit: MMK in million)

	FY 2000	FY 2005	FY 2010	FY 2011
1.Receipts	418,993	1,946,724	5,693,379	6,498,797
2.Expenditures	633,798	2,353,941	7,506,939	8,208,812
3. Gap	(214,804)	(407,217)	(1,813,560)	(1,710,016)

Source: Central Statistical Organization, "Statistical Yearbook 2016", Table 17.01 Summary of the State Budget

This trend is estimated to continue and is likely to expand. The deficit of the public sector increased from 1.1% of GDP in FY 2014 to an estimated 3.3% in FY 2015 as indicated in **Table 1.1-5**, due to a combination of factors such as falling commodity revenues, depreciation of Myanmar kyat, unexpected expenditures for flood and disaster, and an increasing wage.[3] The balance of the public debt compared with GDP is expected to be constant and significant, at approximately 35% in the future.

Table 1.1-5 Trend and Forecast of Public Budget 2013/14-2019/20

(Unit: % of GDP)

	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
a) Revenue	20.2	22.3	19.9	16.8	16.7	16.3	16.8
b) Expenditure	21.7	23.4	23.2	21.3	20.5	19.6	19.9
c) Balance (a-c)	-1.5	-1.1	-3.3	-4.5	-3.8	-3.3	-3.1
Public Debt	34.2	29.5	33.8	33.8	33.8	34.3	34.7

Source: World Bank, "Myanmar Economic Monitor: Anchoring Economic Expectations", December 2016, Table 8

Despite the increasing trend of the budget deficit, more and huge amount of investment is required to the power sector. The recent World Bank report estimates that new investments in electricity generation,

[1] World Bank, "Myanmar Economic Monitor: Anchoring Economic Expectations", December 2016.
[2] http://www.worldbank.org/en/country/myanmar/overview#2
[3] World Bank, "Myanmar Economic Monitor: Anchoring Economic Expectations", Para. 39, December 2016.

transmission, and distribution are required at nearly USD 2 billion (approximately MMK 2,700 billion) per year in the next 15 years in order to achieve universal access to electricity by 2030.[4]

1.2 Overview of Power Sector in Myanmar

Organizations and Responsibilities

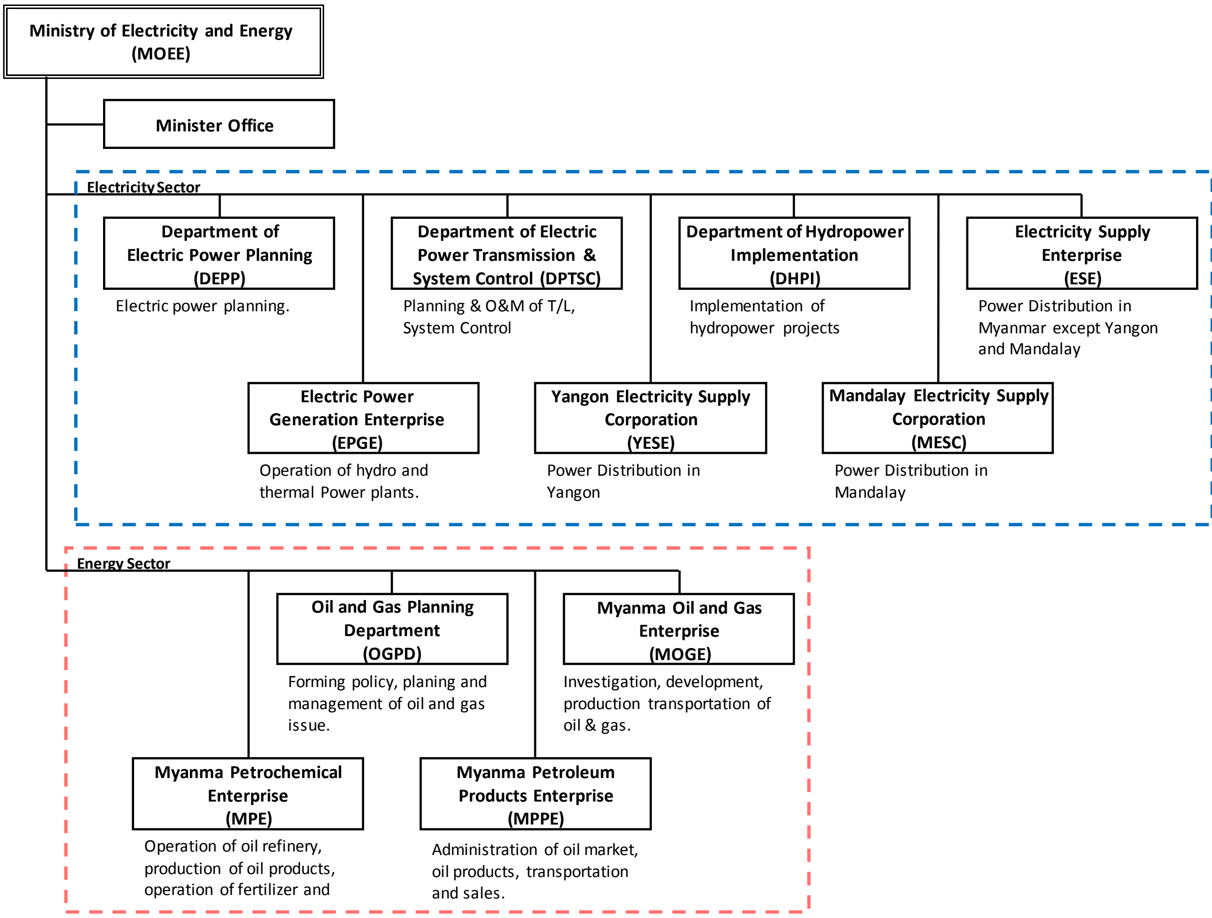
The Ministry of Electricity and Energy (MOEE) is the responsible ministry for the power sector. MOEE also has roles on oil and gas for procurement, production, and transportation. MOEE was established in April 2016 under the structural reform of the government by merging the Ministry of Electric Power and the Ministry of Energy.

The following organizations under MOEE are relevant organizations for this study.

- Electric Power Generation Enterprise (EPGE): Responsible for operation of power plants owned by the government
- Department of Power Transmission and System Control (DPTSC): Planning, operation and maintenance (O&M) and system control of power transmission system
- Yangon Electricity Supply Corporation (YESC): Power distribution in Yangon
- Myanmar Oil and Gas Enterprise (MOGE): Investigation, development, production, and transportation of oil and gas

The organization chart of MOEE is shown below.

[4] World Bank, "Myanmar Economic Monitor: Anchoring Economic Expectations", Para. 45, December 2016. The figures are quoted from the World Bank, "Energizing Myanmar: Enhancing Access to Sustainable Energy for All", 2016.



Source: MOEE and Nippon Koei Co., Ltd.

Figure 1.2-1 Organization Chart of MOEE

Power Generation

Major power sources in Myanmar are hydro (approx. 60%) and gas (approx. 40%). Previously, more than 70% of power was supplied by hydro; however, the percentage was slowly decreasing due to installation of new gas power plant to meet increasing demand. The share of hydropower is 58.6% in 2016.

(1) Gas Fired and Coal Thermal Power Plants

The installed capacities and available capacities are shown in **Table 1.2-1** below.

Table 1.2-1 Installed/Available Capacity of Gas Fired and Coal Thermal Power Plants

	EPGE		IPPs		Total
	Yangon	Other Area	Yangon	Other Area	
a) Installed Capacity (MW)	761	277	281	842	**2,160**
b) Available Capacity (MW)	290	63	256	726	**1,335**
c) Difference (b/a)	38%	22%	91%	86%	**62%**

Note: All plants are gas fired power plants except one IPP (120 MW, coal thermal).
Source: Prepared by the JICA Study Team based on the data published by JETRO

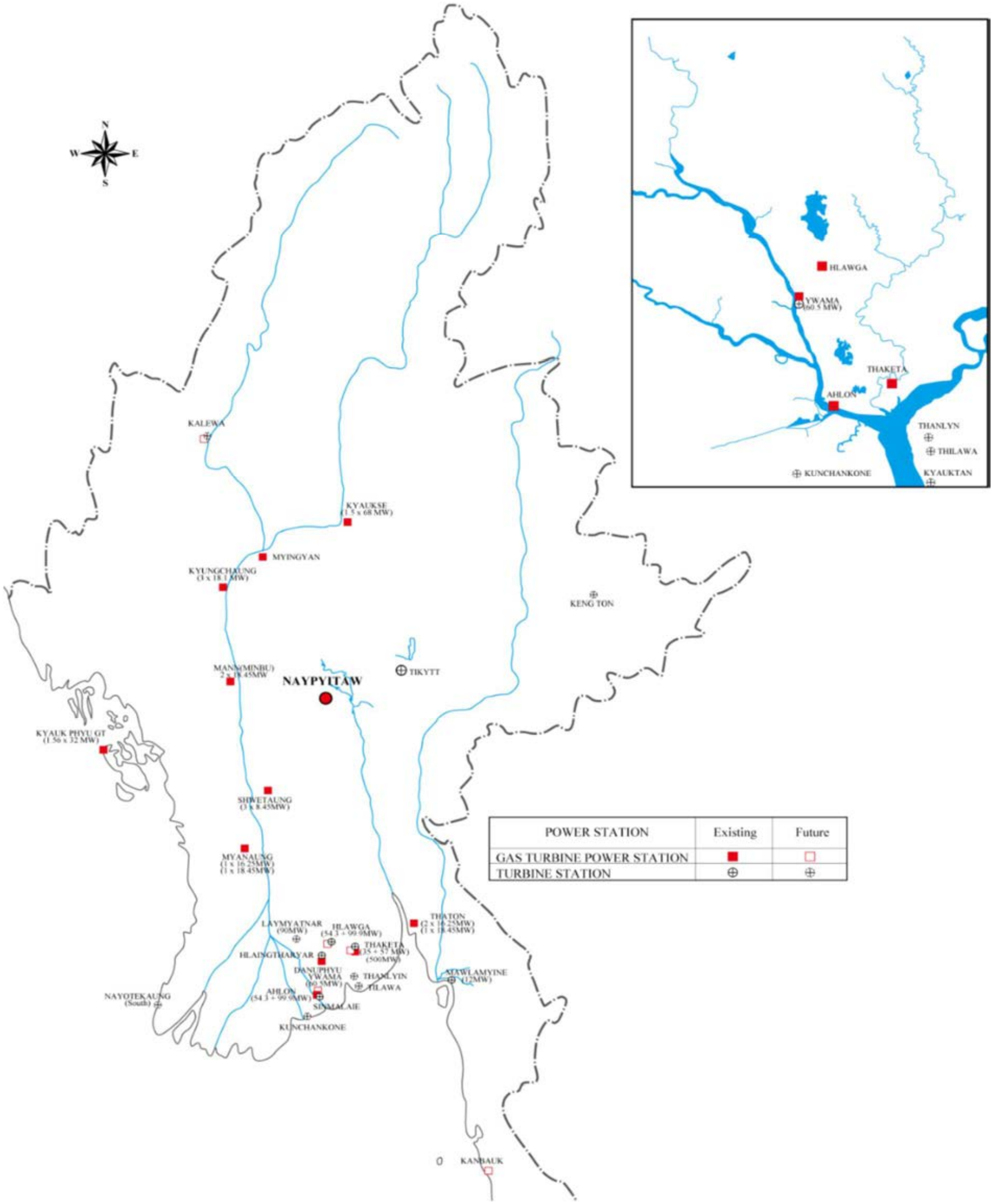
The total installed capacity of thermal power plants (mainly gas) in Myanmar is 2,160 MW; however, available capacity is only 1,335 MW, which is 62% of installed capacity. The reason of the difference is aging facilities mainly owned by EPGE, which can produce much less power than installed capacity.

The list of existing thermal power plants and location of thermal power plants are shown below.

Table 1.2-2 Outline of the Existing Thermal Plants

Location	Owner	Plant	Type	Installed Capacity				COD	Gas RQMT (mmscfd)	Gas Field	Notes
				MW	No	Total					
Yangon	EPGE	Hlawga	GT	33.30	3	99.9	154.2	1996	39.0	Yadana	
			ST	54.30	1	54.3		1999			
		Ywama	GT	18.45	2	36.9	70.3	1980	28.0		
			GT	24.00	1	24.0		2004			Operation Stop by damage on GT H25
			ST	9.40	1	9.4		2004			
			GT	120.00	2	240.0	240.0	2014	80.0		Donated from EGAT
		Ahlone	GT	33.30	3	99.9	154.2	1995	39.0		
			ST	54.30	1	54.3		1999			
		Thaketa	GT	19.00	3	57.0	92.0	1990	29.0	Zawtika	Operation Stop (1unit) by damage on GT
			ST	35.00	1	35.0		1997			Operation Stop by damage on ST
		Thilawa	GT	25.00	2	50.0	50.0	2016	18.8	Zawtica	H25
	Sub-Total (MOEE)						760.7		233.8		
	Zeya (MCP) (Myanmar Company)	Hlawga	GE	1.05	26	27.3	54.9	2013	7.9	Yadana	1st phase in 2013 (Desser-Rand Spain)
			GE	9.20	3	27.6		2015	7.9		2nd phase in 2015 (Rolls-Royce)
	MSP (UPP) (Nyan Shuwe Pyi)	Ywama	GE	4.00	13	52.0	52.0	2013	16.6	Yadana	CAT CG260-16
	Toyo-Thai	Ahlone	GT	41.00	2	82.0	121.0	2013	29.8	Yadana	GE LM6000
			ST	39.00	1	39.0		2014			
	Max Power (CIC)	Thaketa	GE	3.35	16	53.6	53.6	2013	15.0	Yadana	(MITSUI 44%) , MPPL:Singapole, Jenbacher
	Yangon District	Thaketa	GT	25.00	1	25.0	25.0	2017		HFO	
	URSC(Union resources & Enginnnering Co.)	Thaketa	GT	32.00	2	84.0	106.0	2017	no data	no data	Phase I
			ST	42.00	1	42.0		2017		no data	
	Sub-Total (IPP)						281.5		77.2		
	Total (Yangon)						1,042.2		311.0		
Other Area	EPGE	Kyunchaung	GT	18.10	3	54.3	54.3	1974	18.0	Inland	
		Man	GT	18.45	2	36.9	36.9	1980	12.0	Inland	Operation Stop
		Shwetaung	GT	18.45	3	55.4	55.4	1984	27.0	Yadana	
		Myanaung	GT	18.45	1	18.5	34.7	1984	9 (7)	Yadana	Replace planning by JICA
			GT	16.25	1	16.3		1975			Decommitiond
		Thatone	GT	18.45	1	18.5	51.0	1985	25.0	Zawtika	
			GT	16.25	2	32.5		2001			
		Thatone (World Bank)	GT	40.00	2	80.0	119.0	2016	no data	no data	1) Additional 40MW will be operated from Dec. 2017 GE6F.01
				39.00	1	39.0		2016		no data	2) Additional GT (1unit) & ST (1 unit) will be operated from March 2018
		Mawlamyine	GT	6.00	2	12.0	12.0	1980	4.0	Zawtika	
	Sub-total (MOEE)						363.3		86.0		
	VPower	KyaukPhyu	GE	1.56	32	50.0	50.0	2015	no data	Shwe	Rental
	Aggreko	Mingyan	GE	1.04	92	95.0	95.0	2015	no data	Shwe	Rental net output
	Sembcorp/MMID	Mingyan	GTCC		2	225.0	225.0	2018	no data	Shwe	
	APR	Kyaukse	GE	1.50	68	102.0	102.0	2014	27.0	Shwe	
	Siamgas and Petrocemicals	Mawlamyine	GTCC	100.00	1	100.0	230.0	2014	no data	no data	
		Mawlamyine	GTCC	130.00	1	130.0		2015	no data	no data	
	APU	Kanbauk								no data	schedule delaied expected 2020
	Sub-total (IPP)						702.0		27.0		
	Total (Other Area)						1,065.3		113.0		
Grand Total							2,107.5		424.0		

Source: MOEE



Source: MOEE

Figure 1.2-2 Location of the Thermal Power Plants

(2) Hydro Power Plants

Myanmar has much hydropower potentials especially in the mountainous area in northern part of Myanmar such as Kachin State or Shan State. The total installed capacity of hydro power plants in Myanmar is 3,221 MW. However, some independent power producers (IPPs) are exporting power to

China. The capacity for domestic sale is 2,553 MW. **Table 1.2-3** shows installed capacity of hydro power plants.

Table 1.2-3 Installed Capacity of Hydro Power Plants

	EPGE	IPPs	Total
a) Installed Capacity (MW)	2,110	1,111	**3,221**
b) Installed Capacity for Export (MW)	0	668	**668**
c) Installed Capacity for Domestic (b-a)	2,110	443	**2,553**

Source: Prepared by the JICA Study Team based on the data published by METI and JETRO

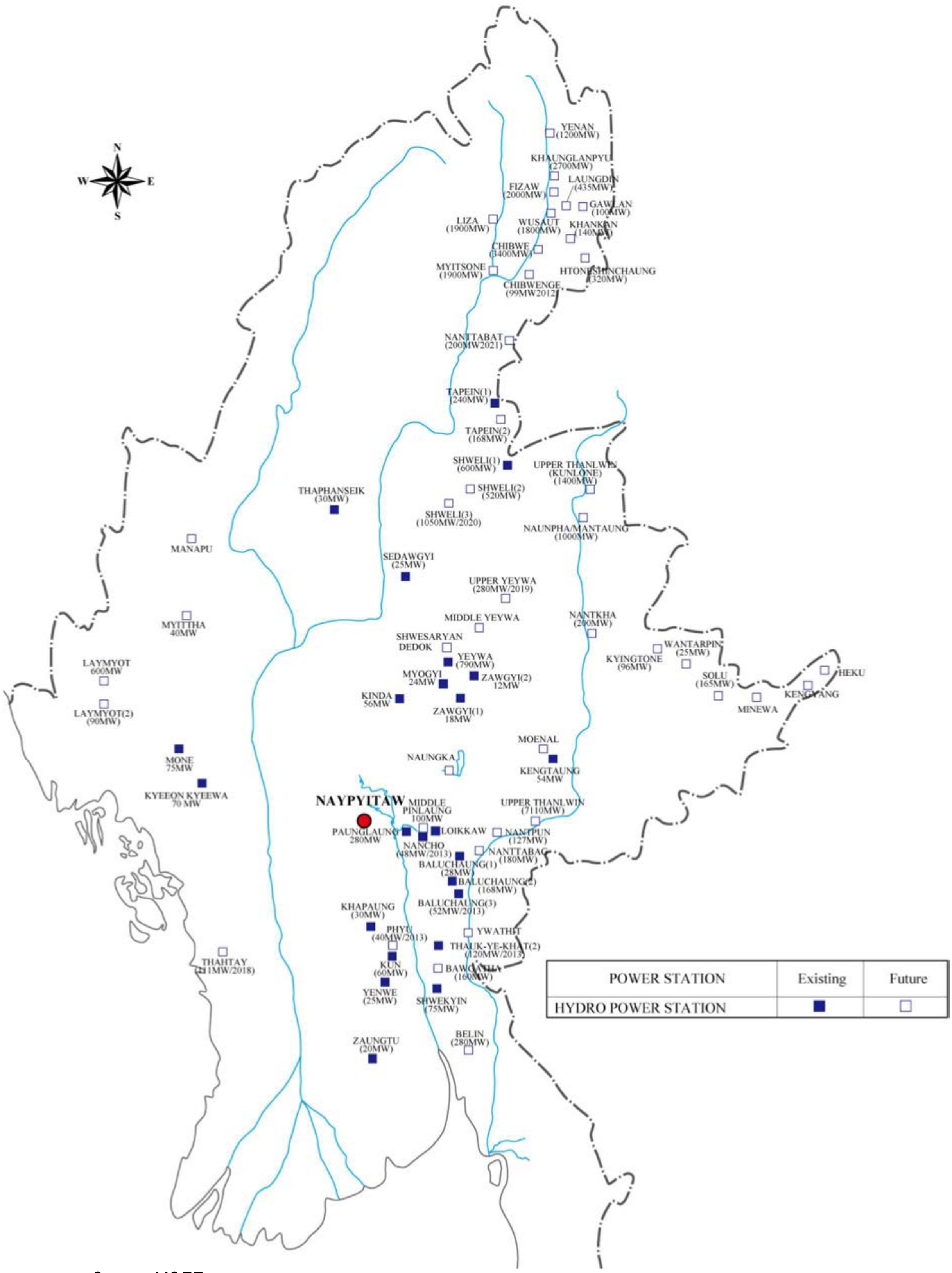
Available power generation is depending on the volume of available water and the capacity of transmission line to send power to the south, especially Yangon, where half of the electricity is consumed.

The list of existing hydro power plants and location of hydro power plants are shown below.

Table 1.2-4 Outline of Existing Hydro Plants

Owner	Plant	Installed Capacity				COD
		MW/Unit	No	Total	Total Sell to Domestic (EPGE)	
EPGE	Baluchaung-2	28	6	168	168	1960
	Kinda	28	2	56	56	1985
	Sedawgyi	12.5	2	25	25	1989
	Baluchaung-1	14	2	28	28	1992
	Zawgyi-1	6	3	18	18	1995
	Zawgyi-2	6	2	12	12	1998
	Zaungtu	10	2	20	20	2000
	Thapanseik	10	3	30	30	2002
	Mone	25	3	75	75	2004
	Paunglaung	70	4	280	280	2005
	Yenwe	12.5	2	25	25	2007
	Kabaung	15	2	30	30	2008
	KengTawng	18	3	54	54	2009
	Yeywa	197.5	4	790	790	2010
	Shwegyin	18.75	4	75	75	2011
	Kun	20	3	60	60	2011
	KyeeonKyeewa	37	2	74	74	2012
	Nancho	20	2	40	40	2013
	PhyuChaung	20	2	40	40	2014
	UpperPaunglaung	70	2	140	140	2014
	Myo Kyi	15	2	30	30	
	Myint Thar	20	2	40	40	
Total EPGE			59	2,110	2,110	
IPP	Shweli-1	100	6	600	400	2009
	Dapein-1	60	4	240	43	2011
	ThaukYeKhat-2	40	3	120	120	2013
	Chipwinge	33	3	99	99	2013
	Baluchaung-3	26	2	52	52	2014
Total IPP			18	1,111	443	
Total EPGE + IPP			77	3,221	2,553	

Source: Prepared by the JICA Study Team based on the data published by METI and JETRO



Source: MOEE

Figure 1.2-3 Location of Hydro Power Plants

(3) Power Generation in Past Years

The power generation in Myanmar is increasing with 13% growth rate, to catch up with the growth in electricity demand. The annual power generation in fiscal year 2010-11 was 8,598.1 GWh and the one in fiscal year 2015-16 was 15,864.8 GWh.

The annual power generation from year 2010-11 to 2015-16 is shown in **Table 1.2-5**.

Table 1.2-5 Domestic Power Production from Year 2010-11 to 2015-16

Fiscal Year*	Type of Power Generation								Total
	Hydro		Gas		Thermal		Diesel		
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	
2010 - 2011	6189.0	72.0%	1736.5	20.2%	640.0	7.4%	32.7	0.4%	8598.1
2011 - 2012	7518.0	72.1%	2119.1	20.3%	749.8	7.2%	38.2	0.4%	10425.0
2012 - 2013	7766.2	70.8%	2377.4	21.7%	770.6	7.0%	50.6	0.5%	10964.9
2013 - 2014	8823.1	72.0%	2794.3	22.8%	568.9	4.6%	60.8	0.5%	12247.1
2014 - 2015	8828.8	62.4%	4977.0	35.2%	285.5	2.0%	64.9	0.5%	14156.3
2015 - 2016	9399.0	58.9%	6225.6	39.0%	285.0	1.8%	55.2	0.3%	15964.8

*Fiscal year starts from April.

Source; DEPP, Central Statistics Bureau

Power Transmission and Distribution

The standard transmission line voltages in Myanmar are 66 kV, 132 kV, and 230 kV. Now, the 500 kV transmission lines are under construction. The Department of Electric Power Transmission and System Control (DPTSC) is the responsible organization for planning, construction, operation and maintenance of power transmission facilities of 132 kV or more. The 66 kV and 33 kV lines related to power stations (power supply line) are still under management of DPTSC. Other lines like 66 kV and 33 kV are not related to power stations, and 11 kV and lower voltage line are under the management of distribution companies like the Yangon Electricity Supply Corporation (YESC) in case of the Yangon area.

For Thilawa area, 33 kV power supply is currently available (as of August 2017) from Thanlyin Substation. However, 2 circuits of 230 kV lines are to be connected soon to Thilawa Substation from Kamarnat Substation and Thanlyin Substation.

Electricity Tariff

Electricity tariff in Myanmar is relatively cheaper compared with other Southeast Asian countries. Around MMK 35 to 50/unit for domestic use and MMK 75 to 150/unit for industrial use. (Applied unit cost varies based on the consumed quantity.) The Electric Power Generation Enterprise (EPGE), the single buyer of electricity, sells electricity to YESC at MMK 58/unit. Such low tariff to domestic consumers is maintained through subsidy from the government. This is one of the major reasons of financial loss of the government.

The current electricity tariff (YESC) is shown in **Table 1.2-6**.

Table 1.2-6 Electricity Tariff (YESC)

Residential Tariff Rates	
kWh/month	**MMK/kWh**
0-100	35
101-200	40
201+	50
Meter Service Fee	*500/month (Single Phase)*

Commercial Tariff Rates	
kWh/month	**MMK/kWh**
0-500	75
501-10,000	100
10,001-50,000	125
50,001-200,000	150
200,001-300,000	125
300,001+	100
Meter Service Fee	*2,000/month (Three Phases)* *5,000/month (CT Meter)*

Source: YESC and JICA Study Team

Chapter 2 Survey Policy

2.1 Implementation Policy for the Survey

2.1.1 Background and Purpose of the Survey

(1) General

The installation capacity of total generation power plant is about 4,651 MW in the Republic of the Union of Myanmar (hereinafter referred to as Myanmar). Whereas, dependable capacity of the plants is only about 1,823 MW, as of November 2015. In particular, the maximum gap at peak load between demand and supply reaches approximately 250 MW. In addition, the peak demand will excess 14,500 MW by 2030 and reinforcement of power supply capacity and national grid are urgent issues according to the National Electricity Master Plan Study (2014).

In July 2016, the Government of Myanmar publicized economic policies in which infrastructure including power supply, road, and port facilities shall be prioritized. Moreover, as energy cooperation to enable industrial development was stated as one of the nine pillars in the Japan-Myanmar Cooperation Program, publicized in November 2016, the importance of cooperation in the power sector is vital between Myanmar and Japan.

In Thilawa Special Economic Zone (SEZ), two units of gas turbine power generation (GTG) plant with rated capacity of 25 MW each have been installed by the Japan International Cooperation Agency (JICA) loan and the power plant supplies to Thilawa SEZ and Yangon. The power demand at Thilawa SEZ, however, will exceed the power supply of the power plant. Considering this forecast, the reinforcement of power supply is an urgent matter for Thilawa SEZ. Furthermore, the power plant is also supplying to Yangon therefore the development plan should be studied to be in accordance to the reinforcement of national grid/distribution line in/nearby Yangon.

In consideration to the above situation, JICA will conduct a study on current power supply situation in/near Thilawa and Yangon, and submit proposal to the Government of Myanmar.

(2) Purpose of the Study

The main purpose of this study is to propose the improvement plan for the power supply in Thilawa SEZ and Yangon in the future through survey on (i) current power supply situation in those areas and (ii) related grid/distribution line and power plants including those at the planning stage.

2.1.2 Current Situation of the Sector and Area

(1) Survey Area and Overview of the Power Supply

The Thilawa SEZ, mainly planned to lure Japanese enterprises, is located approximately 22 km away from Yangon. So far, several cooperation projects have been carried out at the SEZ.

In particular, GTG plants have continuously contribute to the power supply at the SEZ with two units of 25 MW capacities. Surplus of power generation in day time is sent to Yangon through 33 kV distribution line and Thanlyin Substation, which were installed by the same JICA loan project with GTG plant. During nighttime, industry at the SEZ is not activated, so almost all generations by GTG are sent to Yangon as well as surplus in day time.

(2) Recognition of the Current Situation

For conducting this study, the JICA Study Team is planning three stages: (1) recognition of current situation of power supply and identification of problems, (2) conceptual design for selected plan, and (3) reporting.

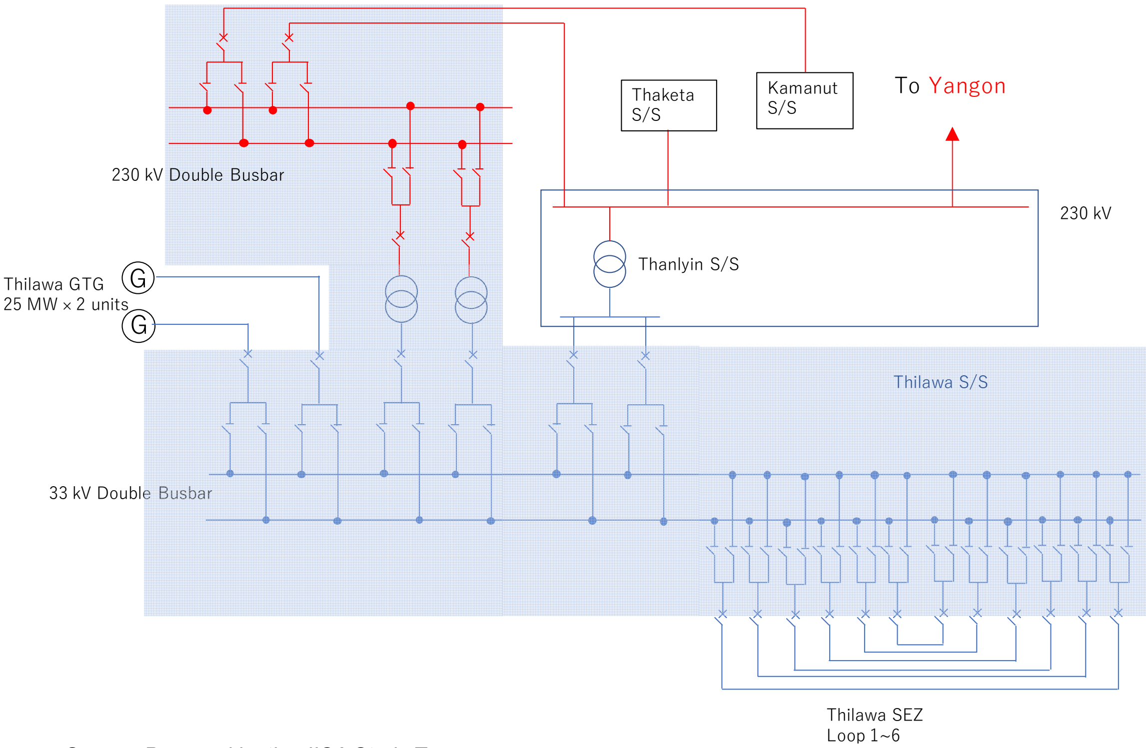
Prior to the conduct of the study, previous studies and implemented projects through JICA loan will be reviewed and appropriate plan will be proposed in consideration of the review and new fact findings through the study.

2.1.3 Issues on the Study

(1) Issue-1: Transmission/Distribution Line and Substation Facilities nearby Thilawa SEZ

1) Power System Facilities nearby SEZ

Figure 2.1.3-1 shows the overview of power system diagram near Thilawa SEZ. Twelve feeders (six loops) at 33 kV are currently equipped to supply SEZ and more feeders will be required as tenants at the SEZ to settle and start their industrial activities.



Source: Prepared by the JICA Study Team

Figure 2.1.3-1 Overview of the Power System Diagram Nearby Thilawa SEZ

2) Power System Facilities for Low Load at Thilawa SEZ

As of July 2017, 37 enterprises have commenced commercial operation of their factories and the peak demand of Thilawa SEZ reaches about 4.5 to 5.0 MW. Until September 2017, GTG was operating at 12.5 MW due to insufficient pressure of gas, but now fuel gas compressor is installed, so it is operating at rated output. After the completion of installation work of gas compressor and obtainment of supply permission for large amount of gas flow, GTG will enable to supply rated capacity of 50 MW from September 2017. As per nighttime demand, it will not be changed since factories are not operating and demand will be low after starting full operation at 50 MW. Therefore, a large proportion of generated power by GTG will be sent to Yangon. In addition, in case the GTG plant is enhanced through installation of heat recovery steam generator (HRSG) and steam turbine (ST), surplus will increase. Thus, power system facilities will be studied in consideration of the above.

(2) Issue-2: Gap between Power Demand and Supply in Yangon

Table 2.1.3-1 discloses demand forecast in Myanmar by region, as of 2014.

Table 2.1.3-1 Demand Forecast in Myanmar by Region

Region	High Case (MW)	
	FY 2012	FY 2030
Kachin	21	185
Kayah	8	162
Kayin	13	165
Chin	3	90
Mon	45	418
Rakhine	10	243
Shan	103	355
Sagaing	98	349
Tanintharyi	52	290
Bago	131	646
Magwe	106	293
Mandalay	457	2,731
Ayeyarwaddy	85	406
Yangon	742	8,209
Total	**1,874**	**14,542**

Source: MOEP Presentation Material

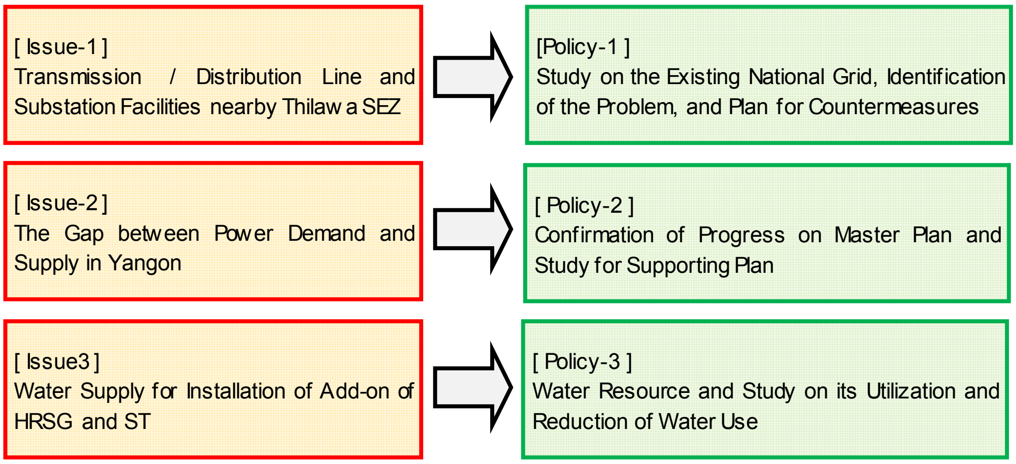
The demand in Myanmar is forecasted with a rapid growth and it is estimated at about 14,542 MW in 2030. The demand in Yangon is predicted at 8,209 MW, which is approximately eleven folds of 2012. As of 2015, the demand and supply gap is analyzed at about 250 MW throughout the nation. Thus, the development in the power sector is an urgent matter.

(3) Issue-3: Water Supply for the Installation of Add-on of HRSG and ST

Enhancement of the existing Thilawa GTG Power Plant is being considered through the adaptation of combined cycle system. One of the issues for the enhancement is subsidence. Utilization of huge amount of underground water will cause subsidence. Therefore, consumption of underground water is strictly limited up to 1,000 t/day for the whole SEZ area and 300 t/day for the GTG power plant. Taking into account the situation, the existing GTG plant will utilize La Gun Byin irrigation water for cooling and NO_x elimination. In case the generation capacity is increased by the installation of HRSG and ST, more water is required than planning. Depending on the method of enhancement of power generation and its requirement of amount of water, water supply can be insufficient only if the current water rights for La Gun Byin and water source will an issue.

2.1.4 Policy on the Study

The diagram of policy on this study is shown below.



Source: Prepared by the JICA Study Team

Figure 2.1.4-1 Issues on this Study and Study Policy for the Issues

Policy-1 Study on the Existing National Grid, Identification of the Problem, and Plan for Countermeasures

At the beginning of this study, the progress of the master plan will be confirmed to the Ministry of Electricity and Energy (MOEE) and EPGE. Besides, demand forecast and required number of feeders (loops) will be asked to the Myanmar Japan Thilawa Development Limited (MJTD). The main points to be confirmed are listed below.

Table 2.1.4-1 Confirmed Items for Power Supply and its Survey and Study Methods

	Items to be Confirmed	Survey Method	Study Method
1	Power supply facilities in Thilawa SEZ	To obtain demand forecast and rewired numbers of feeders from MJTD by year.	To study if additional feeders at Thilawa S/S can be installed in consideration to the information and data from MJTD. - If so, location for new S/S will be studied incorporating the MJTD perspective.
2	Power system facilities for surplus of the generated power output	To confirm issues on sending surplus power to the grid and obtaining related data. To confirm and study surplus power during both peak load and night (for both before and after adaptation of CCGT). To confirm operation policy with low load.	To study power system analysis based on obtained information and data. If the existing grid is not viable for sending surplus power, reinforcement plan will be studied such as upgrading of existing conductors and installation of new transmission/ distribution lines and S/S.

Source: Prepared by the JICA Study Team

Policy-2 Confirmation on the Progress of the Master Plan and Study for Supporting Plan

To confirm the progress of the master plan including reinforcing the existing transmission/distribution lines and substations, is one of the most significant study items because the demand is forecasted in rapid growth. The development plan for new power source, which is not included in the latest master plan, can also play an important role to alleviate the gap between the demand and supply.

Looking at the indigenous gas production in Myanmar, the production for the next ten years seems to drop. Turning to the public awareness on the environment in Myanmar and external factors such as Paris Agreement, it is preferable to enhance generation capacity with add-on combined cycle system to the existing GTG plant rather than installation of new power plant. The existing power plants near Yangon are listed in **Table 2.1.4-2**.

Table 2.1.4-2 Existing Power Plants nearby Yangon

Owner	P/S	Category	Capacity				COD	Gas Field
			MW	No	Total (MW)			
MOEE (Ministry of Electricity and Energy)	Hlawga	GT	33.30	3	99.9	154.2	1996	Yadana
		ST	54.30	1	54.3		1999	
	Ywama	GT	18.45	2	36.9	70.3	1980	
		GT	24.0	1	24.0		2004	
		ST	9.40	1	9.4		2004	
		GT	120.00	2	240.0	240.0	2014	
	Ahlone	GT	33.30	3	99.9	154.2	1995	
		ST	54.30	1	54.3		1999	
	Thaketa	GT	19.00	3	57.0	92.0	1990	Zwtika
		ST	35.00	1	35.0		1997	
	Thilawa	GT	25.00	2	50.0	50.0	2016	
Subtotal (MOEE)						**760.7**		
Zeya (Myanmar Company)	Hlawga	GE	1.05	26	27.3	54.5	2013	Yadana
		GE	1.05	26	27.3		2015	
MSP (Nyan Shuwe Pyi)	Ywama	GE	4.00	13	52.0	52.0	2013	
Toyo-Thai	Ahlone	GT	41.00	2	82.0	121.0	2013	
		ST	39.00	1	39.0		2014	
Max Power	Thaketa	GE	3.35	16	53.6	53.6	2013	
Subtotal (IPP)						**281.1**		
Total (Yangon)						**1041.8**		

Source : EPGE

As of July 2017, Thilawa GTG Plant supplies to Yangon during day and night. Thus, countermeasures will be studied considering reinforcement of the existing Thilawa GTG plant as one of the solutions.

Policy-3 Water Resource and Study on its Utilization and Reduction of Water Use

(1) Water Resource nearby Thilawa SEZ and its Utilization

Additional use of underground water at Thilawa SEZ is not available. In case power generation is enhanced in /nearby Thilawa SEZ, other water resource should be secured from outside of the SEZ. Assumed water resources at present are listed in **Table 2.1.4-3**.

Table 2.1.4-3 Assumed Water Resource for Additional Use at Thilawa SEZ

Water Resource	Amount of Water	Remarks
La Gun Byin Reservoir	10,000 tons/day (by the end of 2018) 32,000 tons/day (by the end of 2019)	Under implementation by JICA loan. The water pipeline is being constructed toward Yangon where 42,000 ton per day will be apportioned to Thilawa SEZ after completion at the end of 2019.
Ban Bwe Gon Reservoir	1,400 tons/day	Completed in 1994. Managed by the Ministry of Agriculture and Irrigation (MOAI). Irrigation is the main purpose for the resource, but some amount of water is sent to household in Kyauk.
Yangon River	Plenty	The area is a tidal zone. Therefore, desalination system in large scale shall be installed.

Source: Prepared by the JICA Study Team

(2) Study on Reduction of Water Consumption

One of the enhancements for power supply is adaptation of combined cycle system to the existing 50 MW plant. In consideration to securing water resource at Thilawa SEZ, cooling method will be examined with cooling tower type and air cooling type with air fins. The comparison between those cooling methods and amount of water consumption will be studied and feasible method will be justified.

The comparison between wet cooling and dry air-cooled system is shown below.

Table 2.1.4-4 Comparison between Wet Cooling and Dry Air-cooled System

Items	Wet Cooling System	Air-cooled System
Heat Removal by	Water evaporation	Air convection and radiation
Plant Efficiency	Base	Lower (about 2%)
Turbine Back Pressure	Base	Higher (Cause of low efficiency)
Cost (Capital)	Base (1.0; <US 44/kW>)	Higher (3.0-3.5)
Cost (Operational)	Base (1.0; <US 17/kW>)	Higher (3.0-3.5)
Auxiliary Power	Base	Larger (more fans)
Water Consumption	Moderate amount	Less
Maintenance	Mechanical type: Fans Natural type: No motor	Much more fans
Wind Effect	Base	Large
Actual Site	Cool to hot area	Cold to cool area

Source: Prepared by the JICA Study Team

2.2 Methodology for the Implementation of Survey

2.2.1 General Work Flow

In this study, the JICA Study Team sets three stages: I) Confirmation of Current Situation and Identification of Problems, II) Conceptual Design, and III) Reporting and Discussion.

<First Stage> Confirmation of Current Situation and Identification of Problems

- Preparation and Discussion on Inception Report
  - Collection and Analysis of the Existing Document
- Recognition of Current Condition of Power Supply and Identification of Problems
  - Demand in Thilawa SEZ and Yangon
  - Current Condition of Power System
  - Policy of Reinforcement of Power Supply
  - Viability of Policy and Expected Project's Benefit

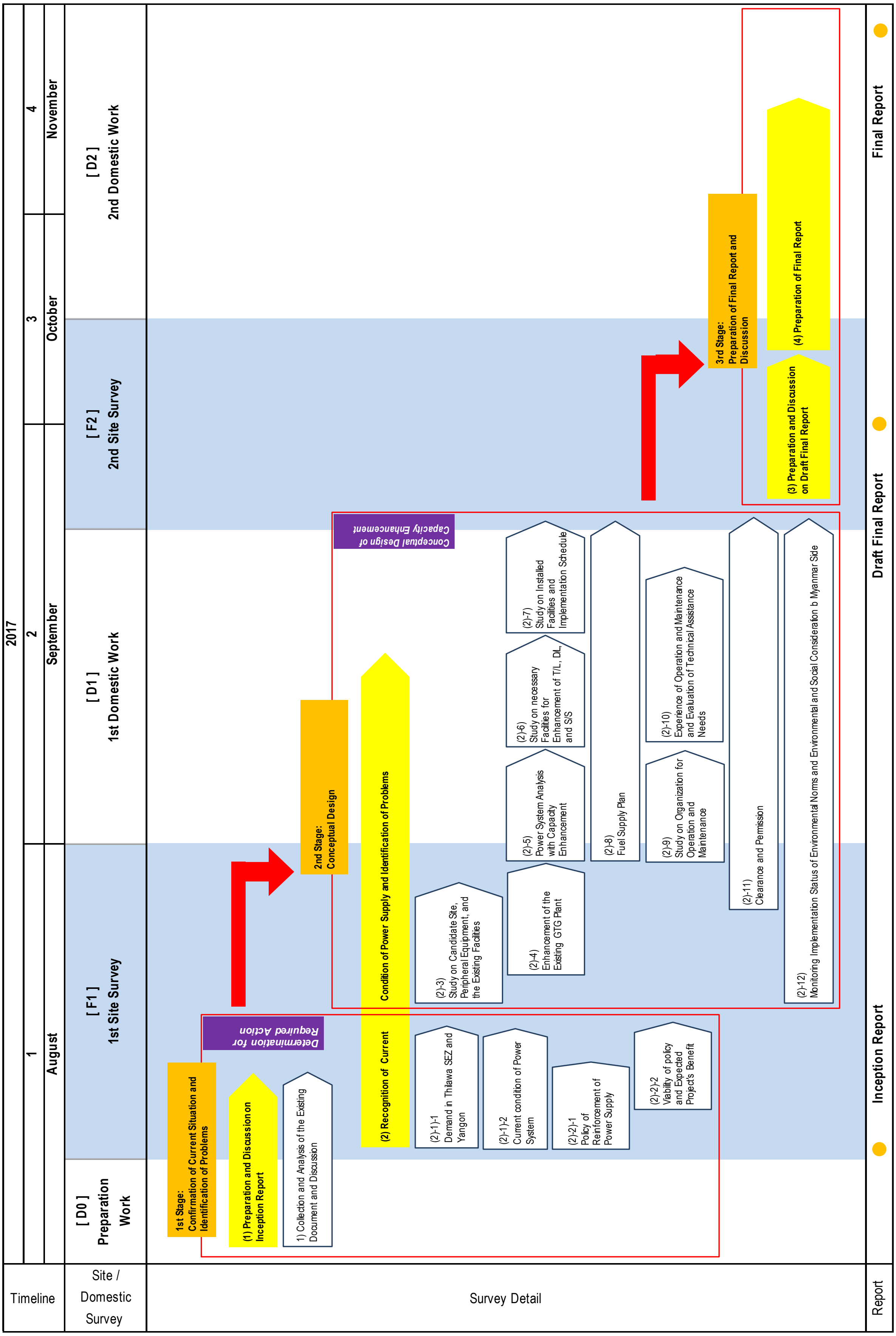
<Second Stage> Conceptual Design

- Study on Candidate Site, Peripheral Equipment, and the Existing Facilities
- Enhancement of the Existing GTG Plant (Single Cycle to Combined Cycle)
- Power System Analysis with Capacity Enhancement
- Study on Necessary Facilities for Enhancement of Transmission and Distribution Line and Substation
- Study on Installed Facilities and Implementation Schedule (Lead Time, Items, Specification, Quantity, and Rough Cost Estimation)
- Fuel Supply Plan
- Study on Organization for Operation and Maintenance
- Experience of Operation and Maintenance and Evaluation of Technical Assistance Needs
- Clearance and Permission
- Monitoring Implementation Status of Environmental Norms and Environmental and Social Consideration by Myanmar Side

<Third Stage> Preparation of Final Report and Discussion

- Preparation and Discussion on Draft Final Report
- Preparation of Final Report and Submission

General work at the original flow is shown below. The schedule was modified due to additional TORs and the date of submission of final report was January 30, 2018.



Source: Prepared by the JICA Study Team

Figure 2.2.1-1 General Work Flow

2.2.2 Study Team Members

The JICA Study Team consists of the following eight members:

- TANAKA Yukao (Mr.), Team Leader / Planning for Thermal Power Plant (I) / Power System Analysis
- SHIOTSUKA Naoyuki (Mr.), Deputy Team Leader / Planning for Thermal Power Plant (II) *(Until August 31, 2017)*
- OGAWA Ryosuke (Mr.), Deputy Team Leader / Planning for Thermal Power Plant (II) *(From September 11, 2017)*
- KOBAYASHI Masanori (Mr.), Thermal Power Engineering
- SHIMIZU Akira (Mr.), Transmission and Substation Engineer
- AZEGAMI Naoya (Mr.), Financial and Economic Analysis
- HIEDA Syunsuke (Mr.), Environmental and Social Analysis (I)
- Ei Ei Mon (Ms.), Environmental and Social Analysis (II)

2.3 Study Schedule

The schedule of this study and milestone are shown below.

- Contract Duration: August 18, 2017 to February 16, 2018
- Submission of Inception Report to JICA: August 18, 2017
- First Site Study: August 21 to September 2, 2017
- Submission of Draft Final Report (Tentative Ver.) to JICA: September 14, 2017
- Second Site Study: September 18 to October 14, 2017
- Submission of Draft Final Report to JICA: End of September 2017
- Submission of Final Report to JICA: January 30, 2018

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Chapter 3 Project Plan and Technical Feasibility

3.1 General

As shown in the current situation in Chapter 2, more power supply is needed in Myanmar.

Both projects can generate additional power by utilizing their own resources (unused heat and idle unit).

Add-on (installation of heat recovery steam generator (HRSG) and steam turbine (ST)) itself does not require any additional gas to generate power since exhausted heat from existing gas turbine (GT) is utilized for steam turbine (ST). Therefore, combined cycle through add-on is highly recommended as a viable project.

Relocation project from Ywama is also recommended since the unit is not so old and the Electric Power Generation Enterprise (EPGE) has a plant to utilize the land after relocation from Ywama. The cost of the relocation and rehabilitation of the idle unit is lower than the cost of a new unit.

3.2 General Policy of the Government of Myanmar on the Project

As mentioned in Chapter 1.2, EPGE, which has the responsibility for the operation of power plants owned by the government, is the appropriate organization for project implementation since Thilawa Power Plant is one of the government-owned plants and additional facility will be installed at the Thilawa Power Plant in this project.

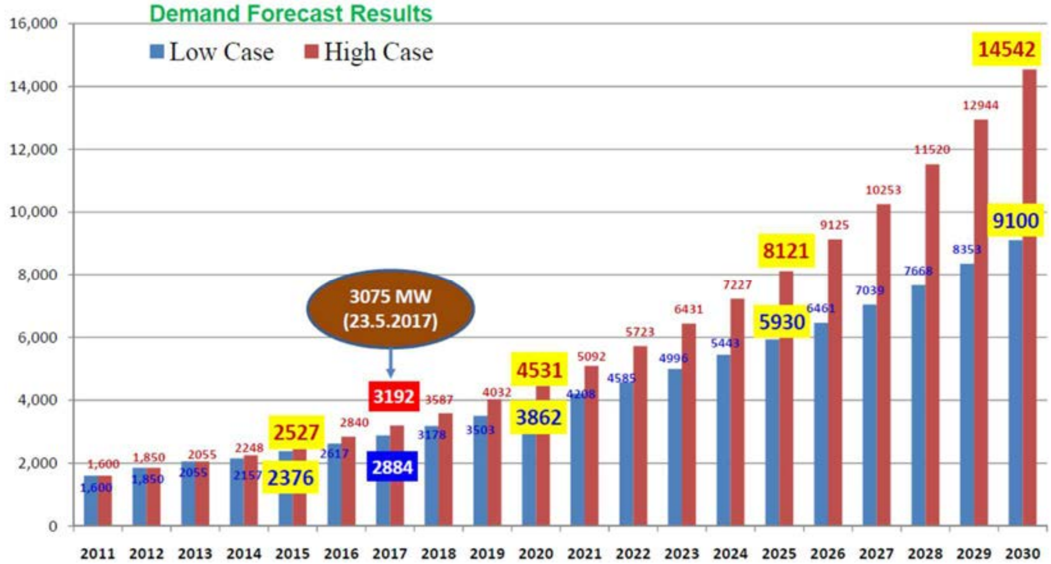
Therefore, the Ministry of Electricity and Energy (MOEE), which is the line ministry for EPGE, is the appropriate ministry to be the responsible organization of this project.

3.3 Study Items for Project Implementation

3.3.1 Demand Forecast and Power Development Plan

Forecast of Power Demand

The future power demand is estimated for two scenarios, namely, low scenario and high scenario, depending on the growth rate of electricity demand. The growth rates of high and low scenarios are 12% and 9%, respectively. The power demand projection in Myanmar until 2030 is shown in **Figure 3.3.1-1**.



Source: "Power Development Opportunities in Myanmar" EPGE, 2017

Figure 3.3.1-1 Peak Power Demand Forecast until 2030

As shown in the figure, the highest peak power demand of 3,075 MW was recorded in May 2017. The peak power demands in 2020 and 2030 for the high scenario are 4,531 MW and 14,542 MW, respectively. And those for the low scenario are 3,862 MW and 9,100 MW, respectively.

Even for the low scenario case, more power development is required in Myanmar to meet the growing demand.

<u>Power Development Plan</u>

To catch up with the rapidly growing demand, there are lots of power development plans by both the government and independent power producers (IPPs).

The sources of energy for new plants are large hydro, gas, and coal thermal. Myanmar has huge hydro potential in the northern part and power generation at low cost is expected. However, the lead time to develop large hydro is quite long and environmental/social impact is also large.

The production of gas will be reduced so imported gas will be mainly utilized for new gas power plant; therefore, the generation cost will be higher than that of hydro.

Myanmar has coal resources; however, the construction of coal thermal plants is difficult due to the opposition of the local residents since it is believed that the environmental issues of emission are harmful.

Each power source has advantage and disadvantage. Recently (2017), however, several high officials of the government suggest the most possible option.

Table 3.3.3-1, **Table 3.3.3-2**, and **Table 3.3.3-3** show the lists of planned and under construction hydro, gas, and coal thermal plants, respectively.

Table 3.3.3-1 Planned and Under Construction Hydropower Plants

No.	Plant	Owner	COD(year)	Capacity
Under Construction				
1	Upper Nanhtwan	EPGE	2020/2021	3
2	Thahtay	EPGE	2020/2021	111
3	Upper Keng Tawn	EPGE	2020/2021	51
4	Upper Yeywa	EPGE	2020/2021	280
5	Shweli-3	EPGE	2020/2021	1,050
Total EPGE				1,495
6	Upper Baluchaung	EPGE/IPP	2020/2021	30
7	DeeDoke	IPP	2020/2021	66
8	Middle Paunglaung	IPP	2020/2021	100
Total IPP				196
Total Under Construction				1,692
Planned Project (1)				
9	Bawgata	EPGE		160
10	MiddleYeywa	IPP		175
11	UpperBu	EPGE		150
12	Manipur	IPP		380
13	Saingdin	IPP		76
14	Laymro	IPP		500
15	Shweli-2	IPP		520/260
16	Dapein-2	IPP		168/84
17	Chipwi	IPP		3400/1700
18	Laza	IPP		1900/950
19	Wutsok	IPP		1800/900
20	Pisa	IPP		2000/1000
21	Kaunglanghpu	IPP		2700/1350
22	Yenam	IPP		1200/600

No.	Plant	Owner	COD(year)	Capacity
Planned Project (2)				
23	Gawlan	IPP		100/50
24	WuZhongze	IPP		60/30
25	Lawngdin	IPP		435/217
26	HkanKawn	IPP		140/70
27	Tongxingjao	IPP		320/160
28	Kunlong	IPP		1400/700
29	Ywathit(Thanlwin)	IPP		4000/2000
30	Hutgyi	IPP		1360/680
31	Mongton(Tasang)	IPP		7110/3555
32	Naopha	IPP		1000/500
33	Mantong	IPP		200/100
34	Lemro-2	IPP		90/45
35	KengTong	IPP		96/48
36	WanTaPin	IPP		25/13
37	Solue	IPP		165/82
38	MongWa	IPP		50/25
39	KengYang	IPP		28/14
40	HeKou	IPP		88/44
41	NamKha	IPP		200/100
42	NamTamhpak(Kachin)	IPP		200/100
43	NamTamhpak(Kayah)	IPP		180/90
44	HtuKyan	IPP		105/53
45	HsengNa	IPP		45/23
46	ThaHkwa	IPP		150/75
47	Palaung	IPP		105/52
48	Bawlake	IPP		180/90
Total Planned Projects				17201/32961

Source: Prepared by Nippon Koei Co., Ltd. using Materials of METI, DEPP, EPGE

Table 3.3.3-2 Planned Gas Fired Power Plants

Location	Owner	Plant	Type	Installed Capacity			COD	Remarks
				MW/Unit	No	MW		
Yangon								
	EPGE	Hlawga	GT	33	3	154	1996	
		Hlaingtharyar	GTCC			400		
		Thaketa				25		
	Total EPGE					579		
	Marubeni /PTT/EDEN	Thanlyin	GTCC	130	2	400	2019	
	Hydro-lancang	Hlawga	GTCC			486		
	BKB	Thaketa	GTCC			503		
	UREC	Thaketa	GTCC			106	2018	
			GTCC			400		2nd phase
	Daewoo + MCM	Shwedaung				70		
	NIHC	Yangon				300		
	Karpower	Yangon				300		
	Total IPP					2,565		
Total Yangon						3,144		
Local								
	EPGE	Thatone	GT	40	2	106	2018	Under construction
				26	1			
		Kyaukphyu	GTCC			50		
		Pahtoelone	GE			12		
	Total EPGE					168		
	APU	Kanbauk	GTCC			200	2019	
	Sembcorp	Myingyan	GT	72	2	225	2018	Under construction
			ST	82	1			
	Total IPP					425		
Total Local						593		
Total EPGE						747		
Total IPP						2,990		
Total EPGE + IPP						3,737		

Source: Prepared by Nippon Koei Co., Ltd. using Materials of METI, DEPP, EPGE

Table 3.3.3-3 Planned Coal Thermal Power Plants

No.		Project	Location	MW	Remarks
JV/BOT Basis					
	1	Kengtong	Shan	660	MOA
	2	Ye (Andin)	Mon	1,280	MOA
	3	Rammazu	Tanintharyi	500	MOA
	4	Kalaywa	Sagaing	540	MOA
	5	Kyauktan	Yangon	600	MOA
	6	Ngayokekaung	Ayeryarwaddy	540	MOA
	7	Tanintharyi (Myeik)	Tanintharyi	1,800	MOU
	8	Tanintharyi (Myitwa)	Tanintharyi (Myeik)	2,640	MOU
	9	Ayeyarwaddy (Ngaputaw)	Ayeryarwaddy	600	MOU
	10	Yangon (Thilawa)	Yangon	315	MOU
	Total JV/BOT Basis			9,475	
BOT Basis					
	1	Yangon (Kungyangone)	Yangon	300	MOU
	2	Myeik (Thanphyoethu)	Tanintharyi	50	MOU
	Total BOT Basis			350	
Total Coal				9,825	

Source: EPGE

3.3.2 Evaluation and Selection of the Options for the Project

The following options are compared and evaluated in terms of 1) technical, 2) financial and economic, and 3) environmental and social aspects:

Table 3.3.2-1 Options for Comparison

	Option 1	Option 2	Option 3	Option 4
Characteristics	Combined cycle of the existing 2 GTs	Relocate and rehabilitate 1 GT and 1 ST from Ywama	1. Relocate and rehabilitate GT from Ywama 2. Combined cycle of 3 GTs	Option 1 + Option 2
Composition of Plant (GT:G:STG)	2:2:1	2:2 (Existing) 1:1:1	3:3:1	2:2:1 1:1:1:
Additional Capacity (MW)	25(ST)	23.2(GT)+9.0(ST)	23.2(GT)+36.6(ST)	25(ST) +23.2(GT)+9.0(ST)
Total Capacity (MW)	75 (50+25)	82.2 (50+32.2)	109.8 (50+59.8)	107.2 (50+57.2)
Estimated water consumption (ton/hour)	250 (ACC) 3,340 (WCC)	83 (ACC) 1,104 (WCC)	375 (ACC) 5,010 (WCC)	333 (ACC) 4,444 (WCC)
EPC cost (Million USD)	*This amount is not published at this public edition of the report.*	*This amount is not published at this public edition of the report.*	Less than Option 4	*This amount is not published at this public edition of the report.*
Environment (air)	Emission gas from existing 2 GTs can comply with target level.	It is necessary to check whether the rehabilitation of 1 GT and ST from Ywama can comply with the target level for emission or not.	Same as the left information	Same as the left information
Environment (water use and ground subsidence)	Difficult to take groundwater due to shortage of groundwater resource and avoidance of ground subsidence. Necessary to take surface water.	Same as the left information	Same as the left information	Same as the left information
Social	No resettlement, acquisition, and income restoration	No resettlement, acquisition, and income restoration	No resettlement, acquisition. Income restoration may be required (but only one or two households).	No resettlement, acquisition. Income restoration may be required (but only one or two households).
Construction period	24-30 months	19 months	(36 months)	30 months

Source: Prepared by the JICA Study Team

1) Comparison and evaluation of the options from technical viewpoint

Effective use of the site

It is important to maximize the utilization of the site space of Thilawa Power Station and to increase power generation output. It is difficult from the viewpoint of space to configure the existing 2 GT + 1 ST as combined cycle (CC) to achieve No. 1 series (75 MW), and make the same 2 GT + 1 ST CC as No. 2 series (75 MW) to make a total of 150 MW power plant. Therefore, Option 3 and Option 4 are the best from the viewpoint of maximum utilization of land.

Construction period

The recommended construction period for Option 4 is 30 months (Thilawa Add-on) and 19 months (Ywama Relocation) respectively. The assumed construction period for Option 3 is 36 months.

Risks due to procedure of construction

When building existing GT Add-on and constructing Ywama Relocation in parallel at the same time, Ywama Relocation may have a situation that affects the entire process after releasing the equipment. Therefore, choosing Option 4 is recommended from the viewpoint of avoiding delays in construction of GT Add-on as separate projects.

Risk concerning the combination of the new GT and old GT (task of performance guarantee)

While the GT of the Thilawa Power Plant is less than two years old, it has already been 17 years since the GT at Ywama Power Station was manufactured (in 2004). In the combined cycle that combines the old and the new GT, it will take time to discuss the performance guarantee required by the manufacturer. When Option 3 and Option 4 are compared, it is better to combine it as a combined cycle and to make each single combined cycle as a simple system. Therefore, it can be said that the system of Option 4 can be simpler than that of Option 3.

Source of cooling water

At present, there is no water supply at Thilawa Power Station, so water injection for NO_x reduction of GT is not done. Even if the output of the Thilawa Power Plant is to be enhanced in the future, supply of water will be an important issue. Therefore, when comparing the air cooling system (ACC) and the water cooling system (WCC), selecting an ACC with an amount of make-up water smaller by one digit reduces the risk of water supply.

As a supplier of cooling water, it is conceivable to divide the water of Rugunbin from the Myanmar Japan Thilawa Development Limited (MJTD), a method to purify and use the water of Yangon River, etc. These arrangements will be under the control of EPGE. It is important to promote EPGE work in consideration of negotiations with related parties and the time required for the Thilawa Power Plant.

Conclusion from technical viewpoint

From the above consideration, it is considered that the selection of Option 4 is the most suitable. In other words, GT of Thilawa Power Plant and GT of Ywama Power Plant have a different combined cycle, and it is considered that the plan to adopt ACC for cooler is appropriate.

<u>2) Comparison and evaluation of the options from financial and economic viewpoints</u>

Financial and economic analysis is intended to compare the financial and economic benefit of the above options by calculating the financial internal rate of return (FIRR) and economic internal rate of return (EIRR) based on the tentative engineering, procurement and construction (EPC) cost.

Estimated electricity generated

Electricity generated by each option is estimated in **Table 3.3.2-3**.

Table 3.3.2-3 Estimation of Electricity Generation

Option 1	175.2 GWh (25 MW x 8,760 hours/year x 80%)
Option 2	225.7 GWh (32.2 MW x 8,760 hours/year x 80%)
Option 3	419.1 GWh (59.8 MW x 8,760 hours/year x 80%)
Option 4	400.9 GWh (Option 1 + Option 2)

Source: Prepared by the JICA Study Team

FIRR and EIRR

FIRR of Option 1 is higher than Option 2. This difference between Option 1 and 2 is influenced by the fact that the additional cost of gas is not incurred in Option 1 but incurred in Option 2 (and Option 3 and 4). Option 3 has the highest FIRR among the options.

Table 3.3.2-4 FIRR

This table is not published at this public edition of the report.

	Option 1	Option 2	Option 3	Option 4
FIRR				

Source: Prepared by the JICA Study Team

The EIRR of each option shows similar figure. Unlike the result of FIRR, the EIRR of Option 2 is slightly higher than that of the other options. This may be due to the fact that the construction of Option 2 is shorter than the other options and the significant amount of economic benefit is achieved one year earlier than in the other options.

Table 3.3.2-5 EIRR

This table is not published at this public edition of the report.

	Option 1	Option 2	Option 3	Option 4
EIRR				

Source: Prepared by the JICA Study Team

3) Selection of the option for the Project

Based on the evaluation of the four options from technical, financial, and economic points of view, Option 4 is selected for further study for the planning, specification and implementation of the Project.

Reasons for selection from the technical viewpoint

The analysis from technical viewpoint puts a priority on 1) the maximum utilization of the land of Thilawa Power Station and 2) the strengthening of generation capacity.

Therefore, Option 4 is the best from the viewpoint of maximum utilization of land. To strengthen the generation capacity as quickly as possible, the relocation of the gas turbine and steam turbine from Ywama Power Station should be started first as its construction period is shorter. Then, the rehabilitation of the gas turbine and steam turbine, and the installation of HRSG and ACC will follow. In line with the rehabilitation work, the construction for the combined cycle of the existing two gas turbine units at Thilawa should also be started.

Reasons for selection from the financial and economic viewpoints

Option 2 alone seems to be less attractive as an investment project from a financial point of view. The result is due to the fact that the incremental cost of gas is incurred in the case of Option 2, while Option 2 does not benefit from the higher efficiency of generation, which can be brought about by introducing the combined cycle to all of the GTs at Thilawa.

Option 3 and 4 are mutually exclusive options. If FIRR of these two options are compared, that of Option 3 is higher than that of Option 4. However, considering a serious technical risk inherent to Option 3, Option 4 is recommended.

3.3.3 Placement of the Power Plant after Implementation of the Project

In Myanmar, power is generated at the hydropower plants in the northern part of Myanmar and at the thermal power plants mostly near Yangon, where much electricity is consumed.

Power generation near the place where much electricity is consumed is reasonable to reduce transmission loss and also good for the stability of electricity supply.

Thilawa Power Plant is located in Thilawa SEZ area, which is a development area under Japanese assistance and also not far from Yangon.

After implementation of the Project, Thilawa Power Plant will still be one of the important power plants to supply electricity to Thilawa SEZ area and Yangon area. As a result, the plant will drive the industry through stable power supply for the SEZ area.

3.3.4 Plan for Fuel Supply

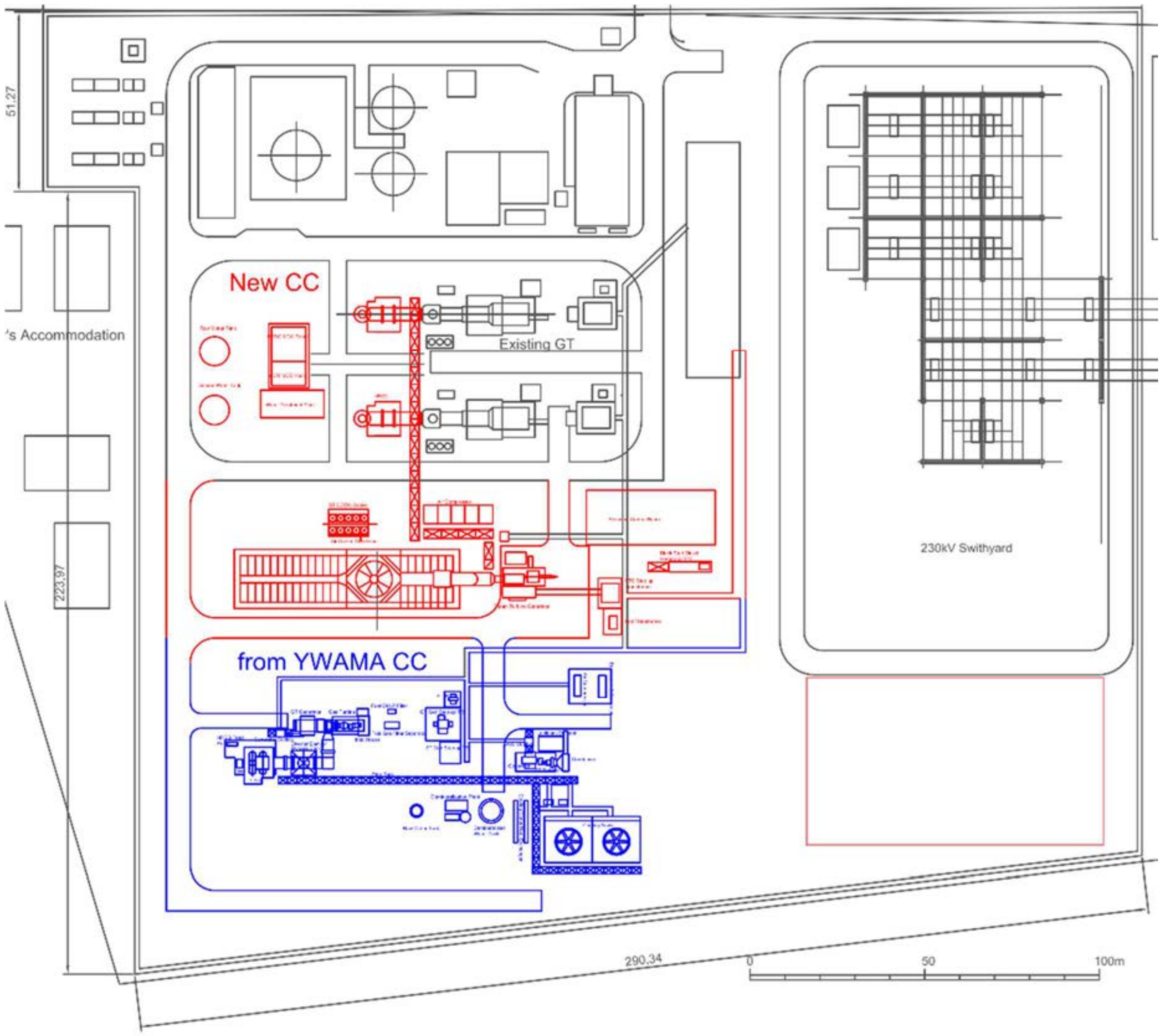
In case of option including "Add-on" (additional steam turbine), no additional gas is needed. In case of option including "Relocation from Ywama", additional gas for 24 MW unit is required.

Domestic gas production in Myanmar will be decreasing because of the available volume of resources. Even under such situation, gas supply to the plant will be secured by Myanmar Oil and Gas Enterprise (MOGE) and EPGE due to the following reasons:

- Gas for Thilawa Power Plant is currently supplied by 20 inch diameter gas pipeline. The capacity of pipeline is more than enough to supply gas for the plant even if options that need more gas are realized (relocation of idle unit from Ywama Power Plant).
- MOGE commented that compared with the whole supply of gas to EPGE, the required gas for the 24 MW unit is very small. Total amount of supply of gas is determined between MOGE and EPGE; however, EPGE will decide the allocation of gas to each power plant. Compared with 319.8 mmscfd (million standard cubic feet per day) which is the total gas requirement for all EPGE gas plants, the requirement for the 24 MW unit, expected at around 9 mmscfd only, is a very small volume.
- For more efficient operation, new plant with better efficiency will have the priority for gas supply. EPGE still has several aging units. Gas supply for such unit will be reduced and newer unit will receive gas within the total allocation to EPGE.

3.3.5 Selection of Equipment

Each option was examined in Section 3.3.2 and Option 4 is recommended as a result. In this section, the equipment for Option 4 will be selected. Option 4 is Thilawa Add-on Plan and Ywama Relocation Plan on the current site, and the schematic layout is as follows. The red shaded area is Thilawa Add-on Plan and the hatched blue area is Ywama Relocation Plan area. The outline plan of each plan and the cooling system of the condenser will be described below.



Source: Prepared by the JICA Study Team

Figure 3.3.5-1 General Plant Layout

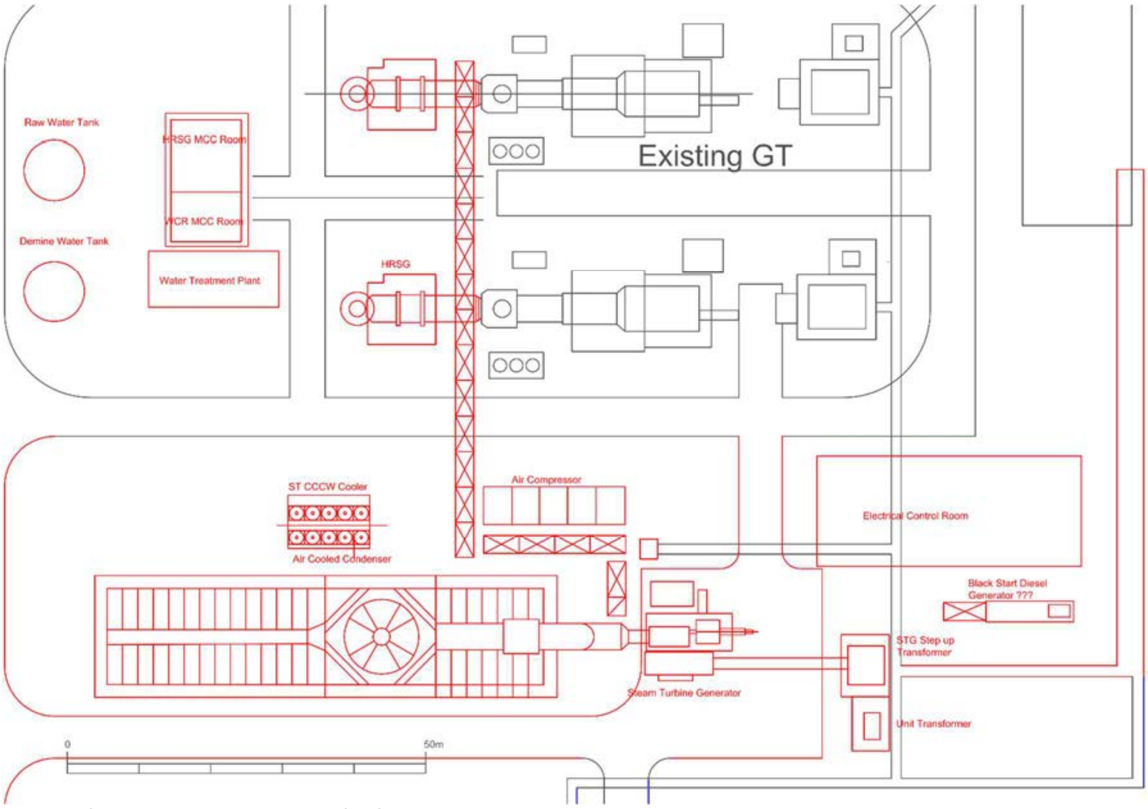
1) Thilawa Add-on Combined Cycle

In the case of the Thilawa Add-on Plan, the work involves the removal of the existing GT exhaust tower, installing HRSG, and moving the existing GT exhaust tower to its back. At the position of the existing GT exhaust tower, a diverter damper and an exhaust tower will be newly installed.

The steam generated by the two HRSGs is merged and sent to the newly established steam turbine via the rack. Cooling water is required to make the exhaust of the steam turbine ascites, but this cooling water adopts the air cooling system. (Details of the cooling method selection will be described later.)

The air cooling tower occupies a large space at the bottom of the layout.

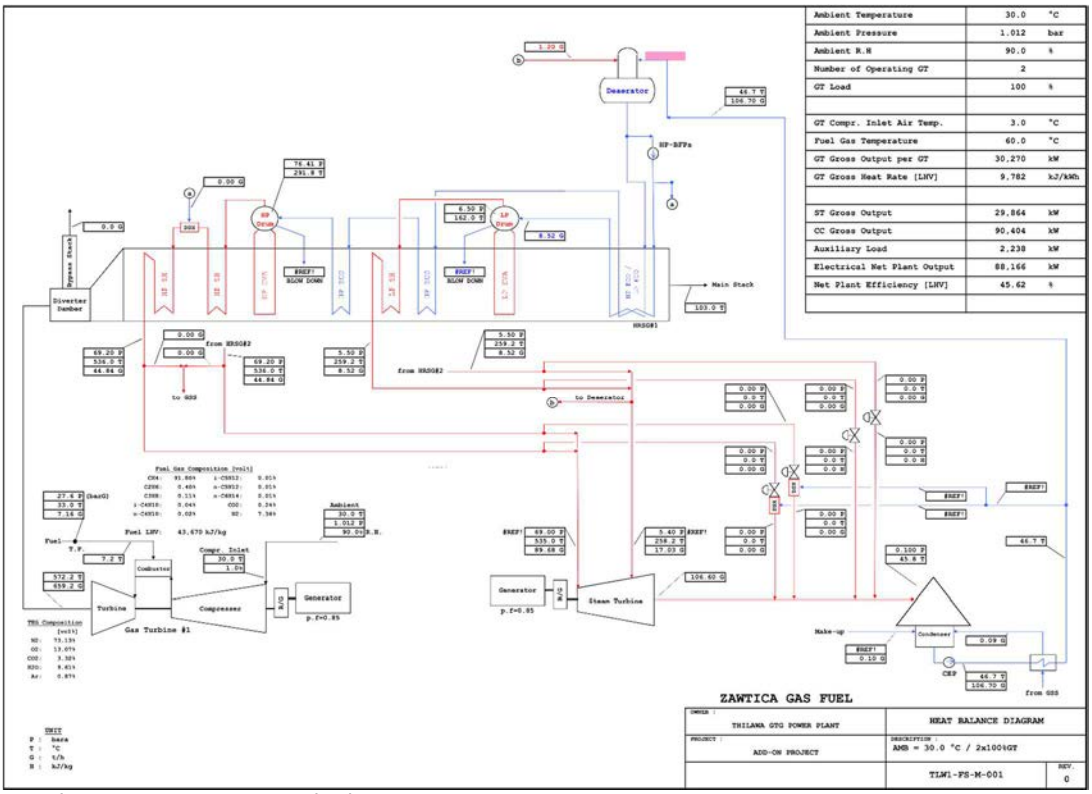
In addition, although water supply tank, water treatment device, and an electric room are installed behind the exhaust tower (on the left side of the layout), a comprehensive layout plan including Ywama Relocation is necessary. Similarly, it is necessary to consider air cooling coolers and the like installed at the bottom of the layout.



Source: Prepared by the JICA Study Team

Figure 3.3.5-2 General Plant Layout for Thilawa Add-on

From the HRSG installed by combined cycle, there is a plan to extract high pressure steam and low pressure steam and send it to the steam turbine. A typical heat balance in this case is shown below.



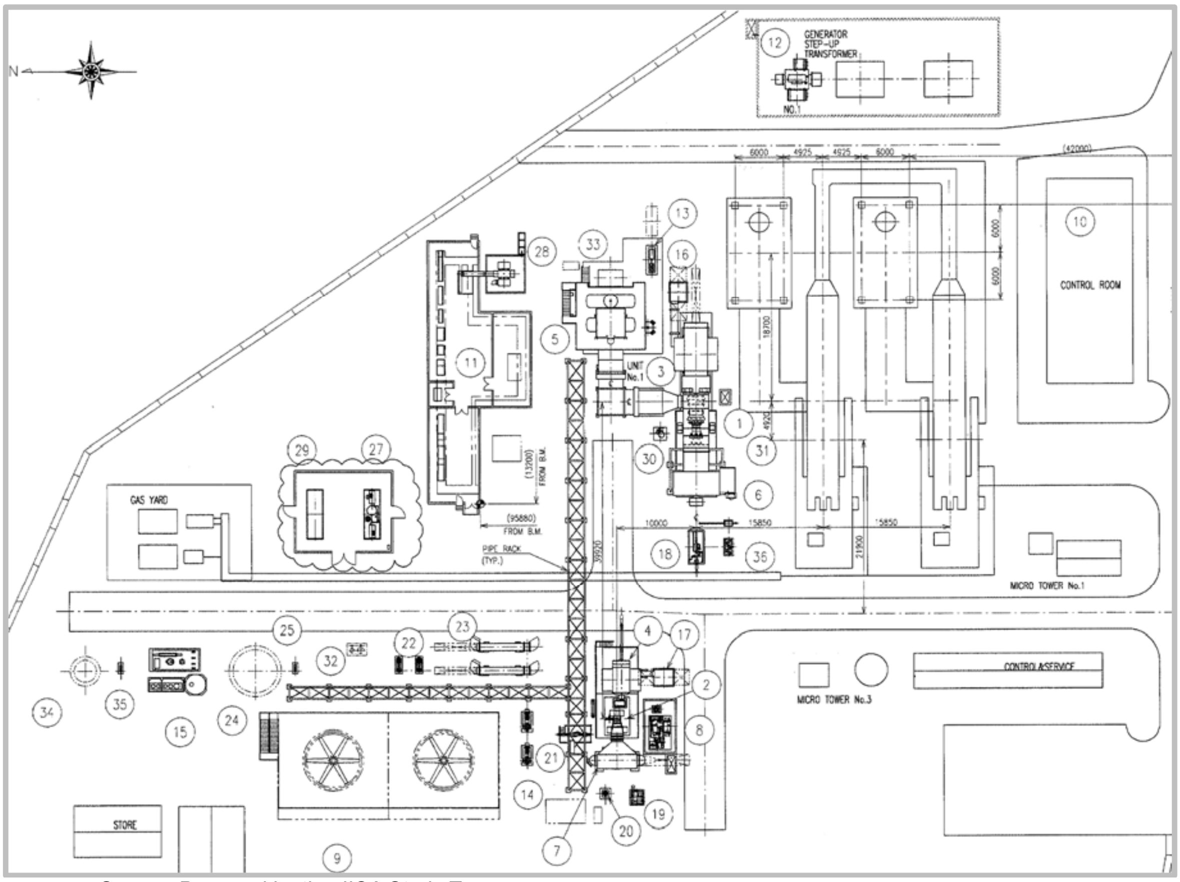
Source: Prepared by the JICA Study Team

Figure 3.3.5-3 Typical Heat Balance of Thilawa Power Plant

2) Ywama Relocation Combined Cycle

This project will relocate the gas turbine package and the steam turbine currently installed at Ywama Power Station to Thilawa Power Station and repair it.

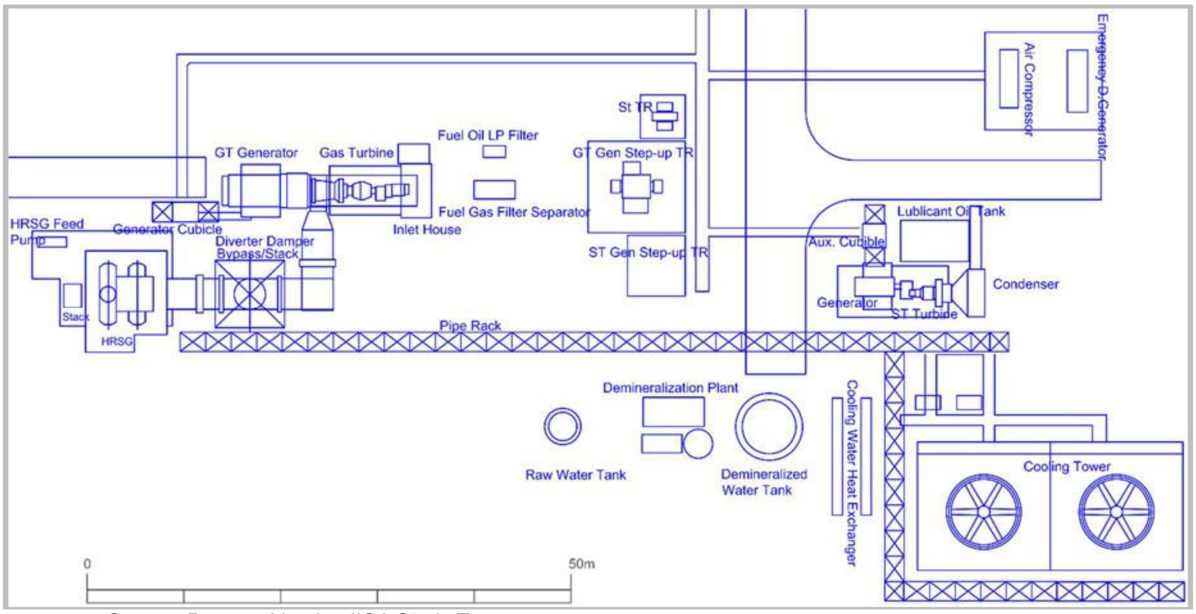
The current layout of Ywama Power Station is as follows. Since the cooling tower is made of concrete, it is discarded and a new air cooling cooler is newly established. Since the transformer for the steam turbine generator was diverted to what was over 40 years ago, this is also newly established. The HRSG will also establish this to avoid the risk of renovation use.



Source: Prepared by the JICA Study Team

Figure 3.3.5-4 Existing Layout of Gas Turbine and Steam Turbine Generating Facilities of Ywama Power Station

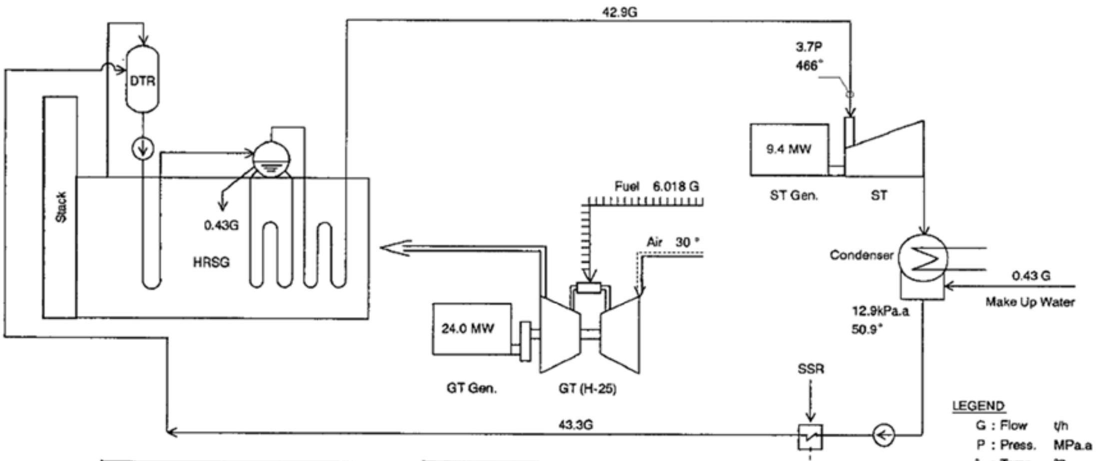
The layout when moving from Ywama to Thilawa is planned as follows. However, as Thilawa's existing power generation facilities are combined at the same time, it is necessary to adjust the layout plan.



Source: Prepared by the JICA Study Team

Figure 3.3.5-5 General Plant Layout for Ywama Relocation to Thilawa

There is basically no change in the line when relocating from Ywama to Thilawa. It can be said that changing the cooling system of the condenser from the cooling tower system to the air cooling system is a major change. The following is a typical Ywama system diagram:



Performance	
Plant Output (Gross)	33.4 MW
(Gas Turbine	24.0 MW)
(Steam Turbine	9.4 MW)
Plant Efficiency (LHV)	43.9 %
Fuel Heating Value (LHV)	45469 kJ/kg

Conditions	
Load	100 %
Ambient Temperature	30 °C
Relative Humidity	85 %
Ambient Pressure	101.33 kPa
Fuel	Natural Gas

Source: Prepared by the JICA Study Team from As Built Drawing

Figure 3.3.5-6 Heat Balance Diagram (Natural Gas, 30 ºC) of Ywama Power Plant

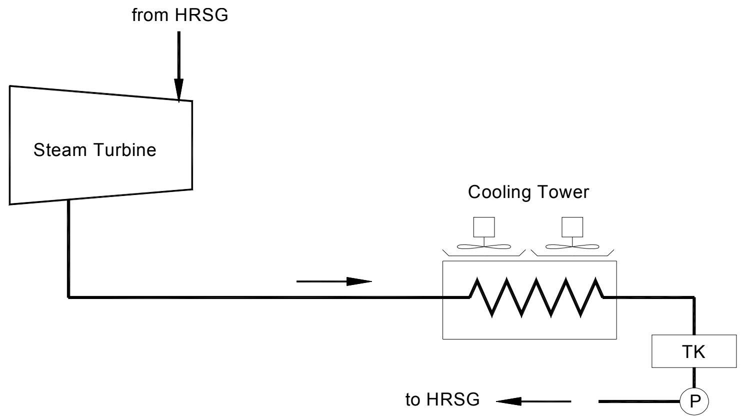
3) Consideration of Cooling Method

There are four considerable options for the cooling method for this project. Each has advantage and disadvantage, e.g., cost, efficiency, necessary land for piping and/or sedimentation basin, and operation and maintenance (O&M).

Ultimately, it is recommended to select an air-cooled cooling system with a small amount of makeup water for cooling water. **Figure 3.3.5-7**, **Figure 3.3.5-8**, **Figure 3.3.5-9**, and **Figure 3.3.5-10** show the cooling methods.

Air Cooled Condensers

Purified water is needed for supplemental water.

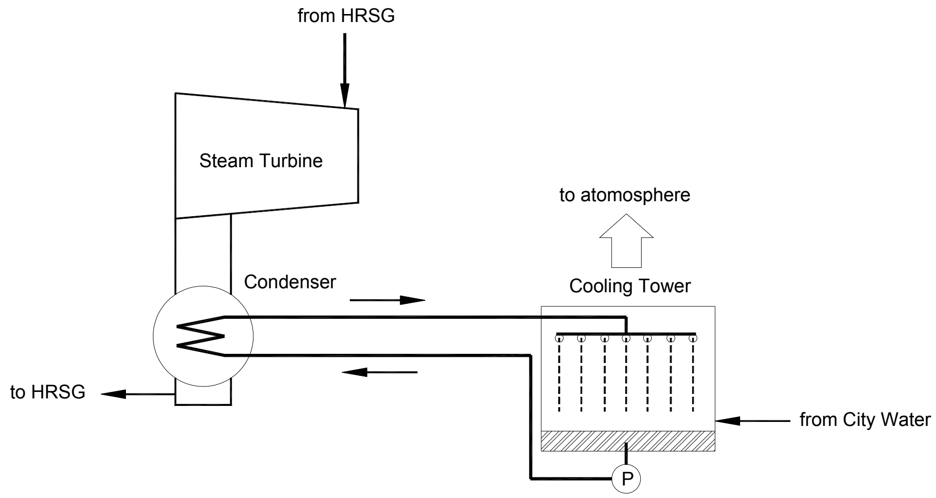


Source: Prepared by the JICA Study Team

Figure 3.3.5-7 Air Cooled Condensers

Water Cooled Condensers (WCC) by Purified Water

Huge amount of water supply is needed.

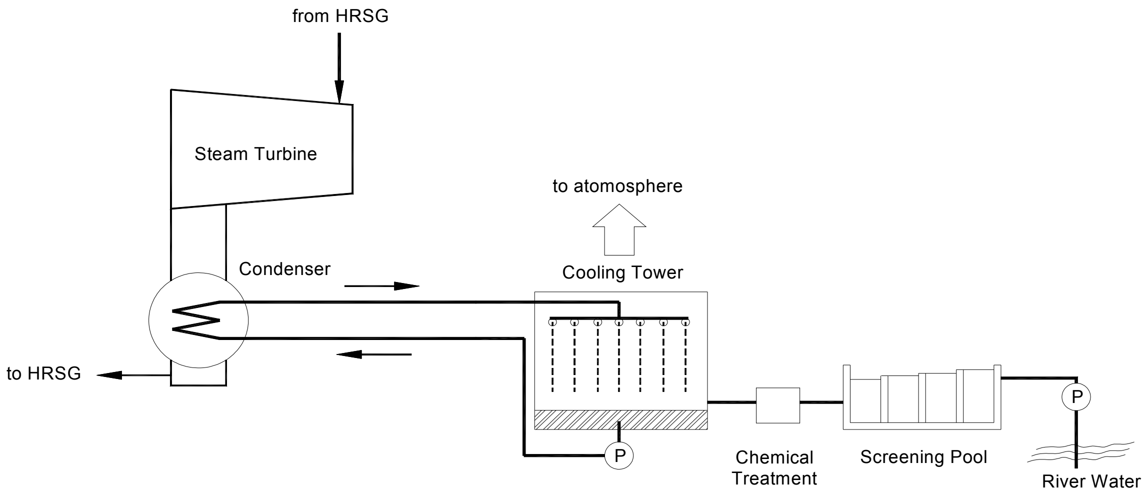


Source: Prepared by the JICA Study Team

Figure 3.3.5-8 Water Cooled Condensers (WCC) by Purified Water

Water Cooled Condensers (WCC) by Water from Yangon River

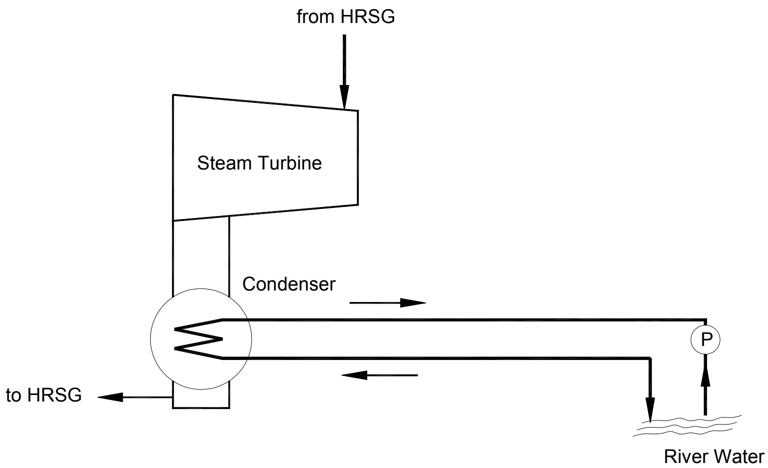
Chemical treatment facility and screening pool are needed.



Source: Prepared by the JICA Study Team

Figure 3.3.5-9 Water Cooled Condensers (WCC) by Water from Yangon River

<u>Water Cooled Condensers Cooled by Water Directly from Yangon River</u>



Source: Prepared by the JICA Study Team

Figure 3.3.5-10 Water Cooled Condensers Cooled by Water Directly from Yangon River

Table 3.3.5-1 shows summarizes the amount of cooling water required. **Table 3.3.5-2** shows summarizing the possible sources of water. **Table 3.3.5-3** shows a comparison of the features of ACC and WCC.

Table 3.3.5-1 Required Water Amount for Thilawa Power Station

	Intended use	Case		Required Water (ton/day)	Candidate for water source	Remarks	Maximum Case	Minimum Case
1	Injection water for GT	for 2 units of GT's		722	Zarmani-Inn Reservoir	*1		
		for 3 units of GT's *5		1,083	Rugunbin Reservoir	*2	1,083	1,083
2	Fire Fighting System	2 times of normal capacity of Raw Water Tank		6	Zarmani-Inn Reservoir		6	6
3	Compressor Water Wash	The number of times of Compressor Water Washing is recommended as one(1) time per month.		0.03	Zarmani-Inn Reservoir		0.03	0.03
4	Cooling Water for Combined Cycle	Air Cooled Condenser (ACC)	for 2 units of GT and one ST	250	Rugunbin Reservoir	*3		
			for 3 units of GT and 2 units of ST	340	Rugunbin Reservoir	*3		
			for 3 units of GT and one ST *5	375	Rugunbin Reservoir	*3		375
		Water Cooled Condenser (WCC)	for 2 units of GT and one ST	3,340	Yangon River?	*3		
			for 3 units of GT and 2 units of ST	4,545	Yangon River?	*3		
			for 3 units of GT and one ST *5	5,010	Yangon River?	*3	5,010	
5	Accommodation	250 family unit = 1,250 person 182L/day * 240person = 43.68 ton/day		228	Zarmani-Inn Reservoir	*4	228	228
							6,327	1,692

*1: In accordance with Sumitomo letter No. L-TLW=TKY=00019 dated April 23, 2017.
*2: Calculated based on the above data.
*3: Estimation
*4: 40 [gallon/day] (= 182[Litter/day]) for a person in accordance with the Design Standard of CP48 (Cord of Practice) of Singapore
*5: One unit of GT from Ywama.
※Reference:
In accordance with Nippon Koei Letter MMTHEL-287/2017 dated June 29, 2017.
In accordance with Nippon Koei Letter MMTHEL-294/2017 dated July 13, 2017.
In accordance with Nippon Koei Letter MMTHEL-301/2017 dated August 18, 2017.

Source: Prepared by the JICA Study Team

Table 3.3.5-2 Examination of Water Source for Thilawa Power Station

Plan	Item	Contents	Location	Supplable amount	Supplable time	Supply negotiation destination	Capital investment content	Evaluation
Plan A	Rugunbin Reservoir	Construction of reservoir with Japanese ODA. 100 thousand tons / day at the end of 2018, and 320,000 tons / day at the end of 2019 (scheduled to be supplied in total of 420,000 tons / day.		Ultimately, 420,000 tons / day in the ODA Project as a whole	End of 2018 - End of 2019	1) Thilawa SEZ Management Committee (TSMC) 2) Myanmar Japan Thilawa Development (MJTD)	Pipe line from the connecting point with Thilawa SEZ to Power Station.	◎
Plan B	Ban Bwe Gon Reservoir	Reservoir built for irrigation around the Kyauk Tan Township area in 1994. The 2014 year JICA Report has surplus water of 1,400 tons / day. * There is a possibility of supplying 766ton / day for GT W / I.		There is surplus of 1,400 ton / day as a whole.	1994 ~	It is necessary to negotiate with the relevant authorities.	Construction of water pipeline from the terminal point with Ban Bwe Gon Reservoir is required.	○
Plan C	Zarmani-Inn Reservoir & Thilawa Reservoir	TSMC and MJTD use all of the water from these reservoirs, so there is no surplus water.				1) Thilawa SEZ Management Committee (TSMC) 2) Myanmar Japan Thilawa Development (MJTD)		△
Plan D	Yangon River	Since the Yangon River is on the west side of the power plant, it is used for cooling water. (W / I and drinking water for GT are B and A above.)	West 1.5 km west of the power plant			It is necessary to negotiate with the relevant authorities.	Conduit pipe and circulating water pump from the intake of Yangon river to power plant. (Heat exchangers may be necessary in some cases.)	×

* Reference material: In accordance with Nippon Koei Letter MMTHEL-287/2017 dated June 29, 2017.

Source: Prepared by the JICA Study Team

Table 3.3.5-3 Comparison of Cooling Methods

		Air Cooled Condenser (ACC)	Water Cooled Condenser (WCC)
1	Required amount of water	Few	Many
2	Area required for installation	Many	Few
3	Equipment cost	Many	Medium
4	On-site construction cost	Few	Many
5	Maintenance and inspection cost	Few	Many
6	Impact on power generation efficiency	Many	Few
	(When it is difficult to obtain water) Comprehensive evaluation	Good	No Good

Source: Prepared by the JICA Study Team

4) Common Subject Matter

The common problem concerning the Thilawa Power Station's combined cycle and the project of relocating and repairing combined cycle power generation equipment from Ywama Power Station is the most important issue for the cooling water problem discussed above.

Since two separate projects will proceed at the same time, it is important that sufficient coordination is made between the projects.

Also, since it is the responsibility of EPGE to make announcement of cooling water, secure gas fuel, and secure electricity transmission network, it is also important to advance the project after clarifying the terms of cooperation between each project.

3.4 Overview of the Project Planning

Option 4 was selected from among the four options in "3.3.2 Evaluation and Selection of the Options for the Project". Option 4 is a combination of Option 1 and Option 2, a project to combine the existing GTs of the Thilawa Power Station into a combined cycle and the combined cycle power generation facility of the Ywama Power Station will be relocated to the Thilawa Power Station, and the damaged GT will be refurbished. The contents of these two projects are described below.

3.4.1 Whole Modification Plan of Generation Facility

Option 4 will implement the two projects of Thilawa Add-on and Ywama Relocation almost at the same time. The situation of the Thilawa Power Plant where these two projects are implemented is shown in **Figure 3.3.5-1** and **Figure 3.4.2-1**.

HRSG, steam turbine, and air-cooled condenser in the area will be installed where the existing gas turbine is installed.

In the area on the south side, there is a plan to place a new set of combined cycle equipment relocated from Ywama.

When the projects are decided, mutual coordination between these two projects is necessary. The outline of the plan for each project at the present time is described below.

Thilawa Add-on Project

The existing two gas turbines currently operate in a simple cycle. In order to convert this into a combined cycle, the existing exhaust tower is temporarily removed, a bypass damper and a bypass stack are newly established, and then HRSG is installed. The temporarily removed exhaust tower is moved to the latter stage of HRSG.

High pressure steam and low pressure steam generated from HRSG are drawn to the south side of the site and sent to the steam turbine. The steam that worked in the steam turbine is cooled by the air cooling condenser. The ascites circulate through the steam system.

The water treatment facility to secure the makeup water necessary for operation of the steam turbine is planned to be installed on the west side of the exhaust tower, but by being consistent with the plan of Ywama Relocation, it is possible to make effective use of the site.

Ywama Relocation Project

Currently, the combined cycle power generation facility installed at Ywama Power Plant consists of one gas turbine and one steam turbine.

Other mechanical equipment is HRSG, condenser, and cooling tower (made of concrete). The gas turbine is currently stopped due to the gas turbine damage that occurred on April 19, 2014.

The main equipment to be relocated are gas turbine, steam turbine, condenser, and control equipment set. As for HRSG, there is a concern about deterioration of tubes during the stoppage period of three and a half years, so it is a new plan.

Also, since the transformer for the steam turbine was not newly constructed from the beginning but was second hand, it is newly established this time. It is planned to dispose the concrete cooling tower and install a new air cooler.

3.4.2 Machinery Facility Plan and Equipment Modification Work

Regarding the machinery and equipment planning, the current state of the two facilities of Thilawa Add-on and Ywama Relocation will be confirmed and the new project to be done will be outlined below.

Thilawa Add-on Project

The full view of the currently installed gas turbine is shown in **Figure 3.4.2-1**. It is planned to remove the exhaust tower in the photo and proceed with the installation of HRSG and others.

Source: Prepared by the JICA Study Team

Figure 3.4.2-1 Full View of Gas Turbine in Thilawa Power Station

The outline of the equipment of the mechanical (including some electrical) system scheduled to be supplied in this project is shown below.

Again, it is important to coordinate between the two projects regarding the layout.

(1) Steam Turbine System

- Steam Turbine
  Main Stop Valve, Control Valve, Turbine Protection Devices, Turbine Control Panel, Turning Gear, Exhaust Hood and Spray System, Set of Sole Plates and Anchor Bolts, etc.
- Lube Oil System
  Lube Oil Tank, Lube Oil Pumps, Emergency Oil Pump, Lube Oil Cooler, Lube Oil Filters, Vapor Extractor Fan, etc.
- Control Oil System
- Gland Steam System
  Gland Steam Condenser, Gland Steam Exhauster, Steam Seal Regulator, Steam Seal Control Valve, etc.
- Control System
  Electro-Hydraulic Control System, Set of Turbine Supervisory Instruments, etc.
- Generator and Electrical Equipment
  Air Cooled Generator with Brushless Exciter, Set of Generator Air Coolers, Excitation Cubicle, Current Transformers for Generator, Line Side Cubicle, Generator Neutral Grounding Equipment (NGR Cubicle), Generator Protective Relay Panel, Generator Control Panel, Set of 11 kV Non-Segregated Bus Duct between ST Generator and ST GSUT, etc.
- Others for Steam Turbine

(2) Heat Recovery Steam Generator System

- HRSG Heat Generation Section
  HP Super Heaters, HP Evaporators, HP Economizers, LP Super Heater, LP Evaporators, Condensate Pre-Heater, etc.
- Drum for HP and LP
- HRSG Structural Steel
- Blowdown System
- Outlet Stack and Transition
- Gas Turbine Exhaust System
- Boiler Chemistry
- Others for HRSG

(3) Mechanical Balance of Plant

- Main Steam System
- Auxiliary Steam System
- Condenser
- Condensate System
- Condenser Vacuum System
- Feed Water System
- Natural Gas System Common for All Gas Turbine Units
- Closed Cooling Water System for Combined Cycle Equipment

- Plant Water System
- Wastewater Treatment System
- Fire Protection System
- Compressed Air System
- Inert Gas System
- Ventilation and Air Conditioning System

(4) Electrical Balance of Plant

- 230 kV Substation
- Transformers
- MV Switchgear
- Unit and Station Switchgear
- Motor Control Center
- DC Supply System
- Uninterruptible Power Supply System
- Black Start Diesel Generator
- Lighting and Small Power
- Cable
- Raceway and Conduit Material
- Grounding and Lighting System

(5) Control System and Instruments

- DCS System Hardware
- Instrumentation and Control Devices
- Continuous Emission Monitoring System (CEMS)

Ywama Relocation Project

The Ywama Power Plant is currently equipped with combined cycle power generation facilities consisting of GT x 1 unit, HRSG x 1 unit, and ST x 1 unit.

These incidental facilities include a condenser, a water-cooled cooler (cooling tower made of RC), a feed water treatment facility, an electric facility, a control device, etc. The arrangement is shown in **Figure 3.3.5-4**.

The status of the current facilities will be described below.

(1) Gas Turbine

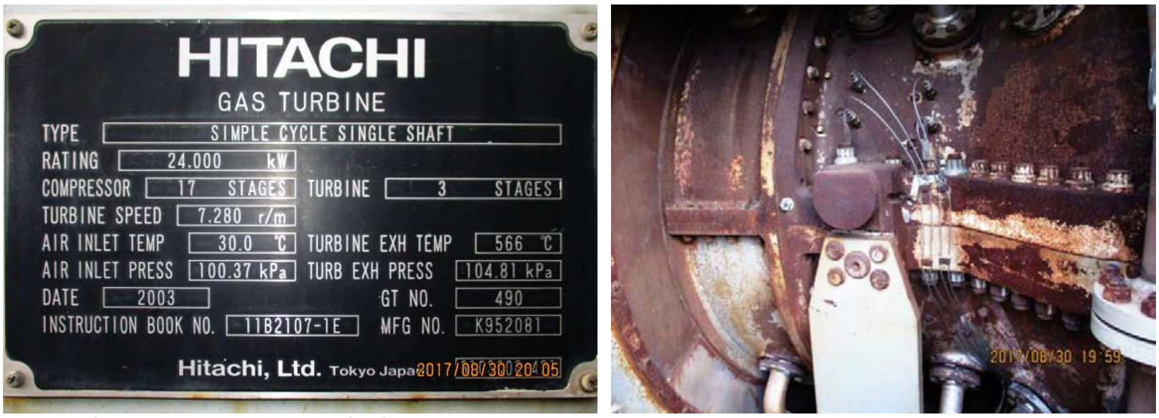
- Type / H-25(28)
- Output / 24 MW @ 30 ºC,
- Manufacturer / MHPS in Japan,
- Fuel / Dual Fuel Type (Natural Gas and Distillate Oil),
- GT Firing Hours / 45,747 hours,

Figure 3.4.2-2 shows the nameplate and internal situation of the gas turbine.

The gas turbine is in a non-operating state due to the accident on April 14, 2014.

Currently, the parts considered to be damaged in the gas turbine are the 2-stage and 3-stage turbine bucket, 3-stage turbine nozzle, and 2-stage and 3-stage turbine shroud. These repairs are required.

In addition to this, replacement of the gas turbine rotor is also necessary depending on the situation.



Source: Prepared by the JICA Study Team

Figure 3.4.2-2 Photo of the Nameplate and Interior of the Gas Turbine in Ywama Power Station

(2) Gas Turbine Intake System

The intake facility is installed at the top of the gas turbine package.

There is a filter room on the frame, and the front has a stand for maintenance and a staircase for access. These placement situations are shown in **Figure 3.4.2-3**.

Source: Prepared by the JICA Study Team

Figure 3.4.2-3 Situation around the Gas Turbine in Ywama Power Station

(3) Exhaust Duct and HRSG

- Type / Single Pressure, Horizontal Gas Flow,
- Pressure / 4.0 MPa,
- Temperature / 469 ºC,
- Manufacturer / Babcock –Hitachi KK (Japan), Manufactured in 2003

The exhaust duct of the gas turbine is sideways, and it is positioned against the HRSG by 90 degrees. HRSG plans to avoid the risk of renovation from the situation where maintenance has not been conducted since the suspension due to the accident on April 14, 2014, and to establish a new one.

The **Figure 3.4.2-4** shows the nameplate of the HRSG.

Source: Prepared by the JICA Study Team

Figure 3.4.2-4 HRSG Nameplate Photo in Ywama Power Station

(4) Steam Turbine

- Type / Single Casing Condensate
- Output / 9.4 MW,
- Pressure / 3.7 MPa,
- Temperature / 466 ºC,
- Manufacturer / Shin-Nippon Zoki in Japan,

The steam turbine is installed outdoors, but the roof is hung. A condenser is installed behind the steam turbine, and condensate is taken out from the hot well in the lower part of the water chamber.

The status of the steam turbine, generator, and condenser is shown in **Figure 3.4.2-5**.

Source: Prepared by the JICA Study Team

Figure 3.4.2-5 Pictures Around the Steam Turbine in Ywama Power Station

(5) Wet Type Cooling Tower (Existing one is scrap)

As shown in **Figure 3.4.2-6**, the existing cooling tower is made of RC and is not subject to relocation. In the future, it will be disposed of.

Also, at the Thilawa Power Plant, a new air cooling cooler is prepared.

Source: Prepared by the JICA Study Team

Figure 3.4.2-6 Pictures of Existing Cooling Tower in Ywama Power Station

The main work to be carried out in this project is shown below. Again, it is important to coordinate the layout between the two projects.

- Uninstall, disassemble, if necessary, and prepare packing to transport
- Transport from Ywama to Thilawa Power Station by barge and/or trailer
- Reinstall and reassemble equipment
- Replace damaged H-25 gas turbine unit's hot gas components and rehabilitate degraded power output fuel consumption
- Inspect major overhaul on gas turbine unit, generators, steam turbine and major BOP equipment
- Inspect all equipment and system, rectify damaged equipment and system, and replace parts as required
- Execute required civil and building works
- Execute pre-commissioning, commissioning and performance acceptance testing of the CCGT plant
- Functional guarantee for 12 months after taking over

3.4.3 Electrical and Control Facilities

The features of this plant are base load and load changing operation. To meet the features of this plant, the purpose of plant control is set for automatic start/stop operation of the plant, which aims:

- To increase safety, reliability, and flexibility on start-up and shut-down.
- To save operator's manpower.

3.4.3.1 Add-on System of Thilawa Power Station

The requirements on the plant operation, control level, control location, etc. are as specified hereunder.

Upon reaching the GT Ready to Start Condition, the GT Start Command shall be issued from the GT-HMI station(s) located in the CCR or Supervisory Start Command from the DCS-HMI Station(s).

Thereafter, the GT control leads the GT from the bearing gear operation to loading of the GT through various startup activities/phases like Speed Up to Purging Speed, Purging Cycle, Speed Down to Firing Speed, Ignition, Heat Soaking, Speed Up toward FSNL, Disengaging Starting Device, Synchronization and Initial Loading, and Futher Loading up to Desired Level as per unit and/or block load demands.

All necessary plant equipment/system – so as to achieve the plant readiness/GT Ready to Start Condition – shall be done from the DCS; the local control facilities for the system/equipment shall be provided with autonomous/proprietary control system and manual operation at field.

With the GT, HRSG Running, and ST Ready to Start Conditions (including the ST exclusive conditions like ST No Trips, Lube Oil and Hydraulic Pressure OK, ST Generator Breaker Open, ST Reset, etc.) are achieved, the ST Start will be issued from the DCS to the ST Controller, Thereafter, the ST Controller leads the ST from steam admission up to loading of the ST through various startup phases/activities like Steam Admission, Heat Soaking, Speed Up to FSNL, Synchronization and Initial Loading, and further Loading Up to the Desired Level as per the block load demands.

3.4.3.2 Relocated System from Ywama Power Station

1. Extent of Plant Control

The extent of the control is shown in the following.

Plant Start of Gas Turbine and Steam Turbine, to target load

When the plant will start up, the following initial conditions have been established:

- Plant electrical system is in service.
- All the system components are properly lined up and commissioned.
- Cooling Water System is filled with water, and in service.
- Auxiliary Cooling System is filled with water, and in service.
- Compressed Air System is in service.
- Lube Oil System and Control Oil System are in service.
- Steam Turbine Turning System is in service.
- Makeup Water System is in service.
- Feed Water System is filled with water.
- HRSG status is on pre-start. (Drum water level down, etc.)

Plant Shut Down

- From the load down of gas turbine and steam turbine, to the shutdown. (i.e., on turning operation)

After gas turbine and steam turbine shutdown, the following operations are manually done:

- HRSG status is on a normal shutdown (Drum water fill up, etc.)
- Feed Water System shutdown
- Makeup Water System shutdown
- Steam and Gas Turbine turning stop
- Lube Oil System and Control Oil System Shutdown
- Cooling Water System shutdown
- Auxiliary Cooling System shutdown

Normal Load Operation

- Load control

Emergency Plant Control

- Emergency shutdown due to trouble which arises from the outside of the electrical system in this plant (33 kV system, 11 kV system, etc.)
- Emergency shutdown due to main equipment trouble (GT, ST, HRSG, and electrical system trouble trip)
- Emergency shutdown due to the internal trouble of GT (Load run-back)

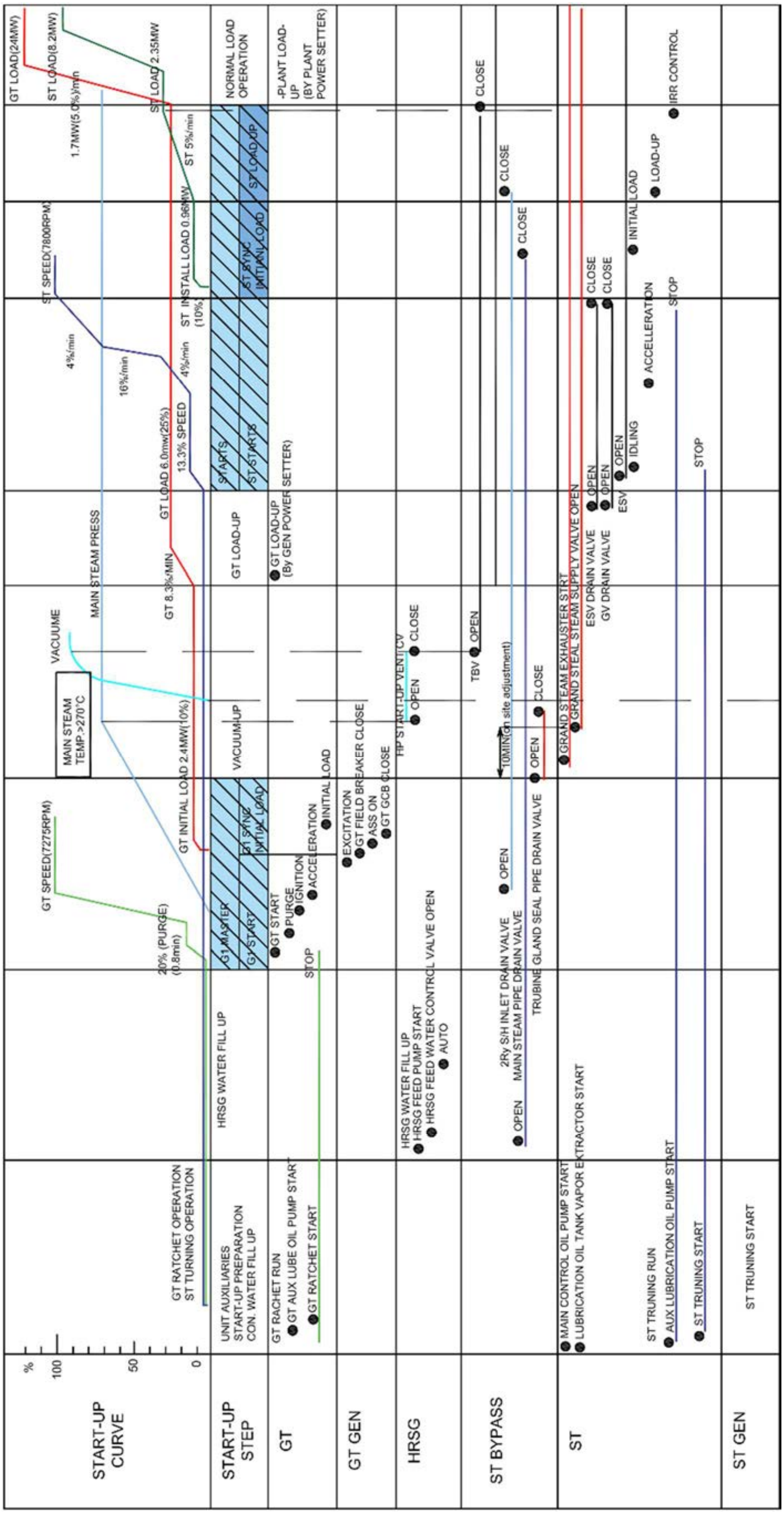
2. Out of Extent of Plant Control

Operations beyond the extent of plant control are those that do not involve the start/stop of GT and ST, and which must be judged by the operator.

- System lined up before plant start up (Valves for instruments)
- Continuously operating equipment (Such as auxiliary cooling water system, vapor fans, chemical dosing system, main instrument and service air system, etc.)
- Operation to perform the maintenance (Such as cooling down of HRSG or turbine, hydrogen supplying and purging system, nitrogen sealing system, chemical cleaning system, steam blowing out system, etc.)
- No reliable sensor (Such as turbid water, etc.)
- Troubleshooting and recovery operation for plant trouble
- Operation to perform the maintenance (Such as cooling down of GT and ST, etc.)

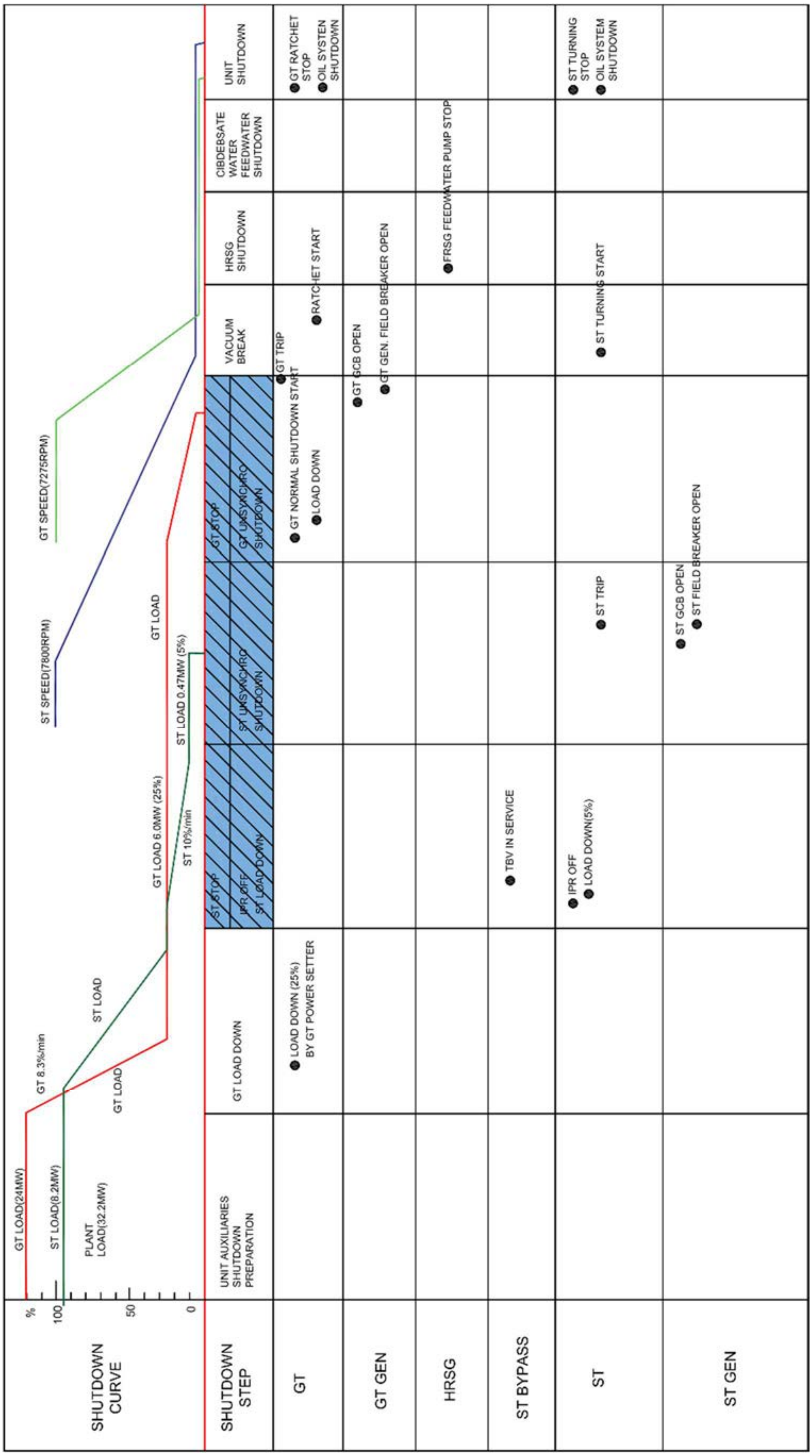
3. Plant Control

The plant controls are as shown in **Figure 3.4.3-1** and **Figure 3.4.3-2**.



Source: Prepared by the JICA Study Team from the As-Built Drawings

Figure 3.4.3-1 Plant Control Procedure for Start Up Operation



Source: Prepared by the JICA Study Team from the As-Built Drawings

Figure 3.4.3-2 Plant Control Procedure for Shutdown Operation

3.4.3.3 Connection of Add-on System of Thilawa Power Station to the System

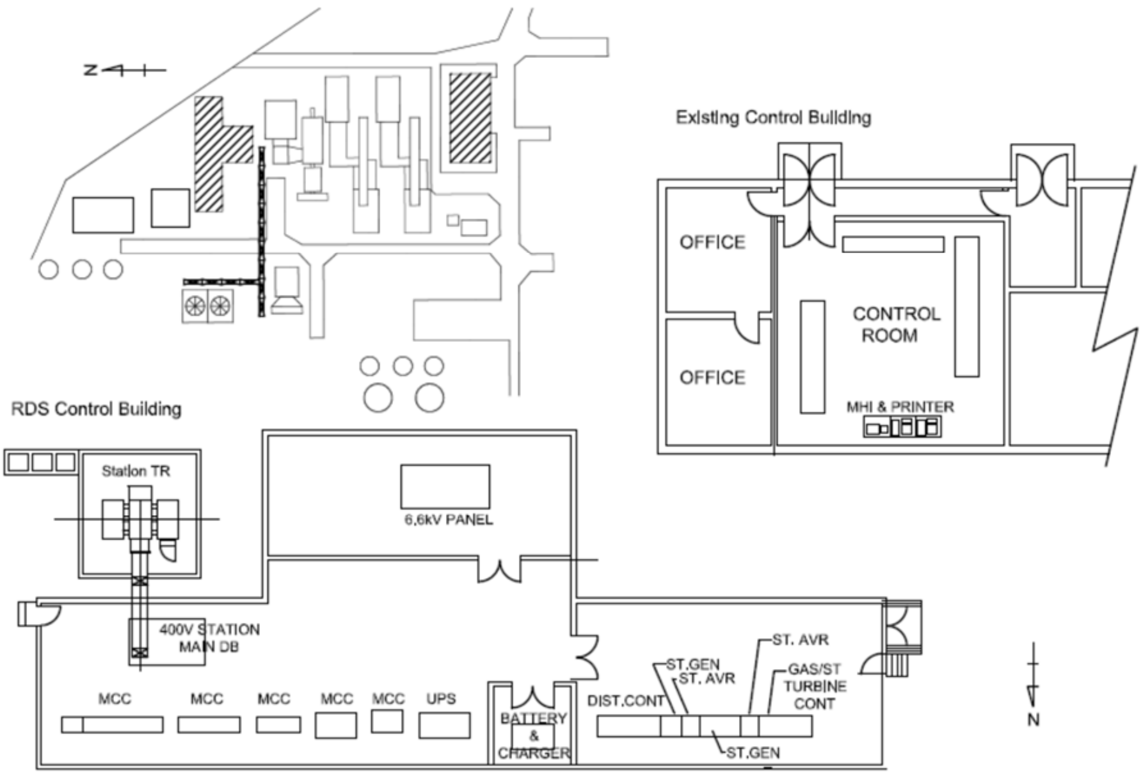
The output voltage of the generators of the add-on steam turbine shall be 11 kV. Step-up transformer to 33 kV with 30 MVA shall be installed. The secondary (33 kV) circuit of the transformer shall be connected to the 33 kV GIS double bus bar system stated in Section 3.4.3.5. The control equipment for the steam turbine and generator shall be installed in the new control building.

3.4.3.4 Relocation of Ywama Power Station to the System

The output voltage of both the generators of the gas turbine and steam turbine is 11 kV. Each output circuit of the generators shall be step up to 33 kV by separate step up transformers.

The step-up transformer of 11/33 kV, 11 MVA for the steam turbine generator shall be relocated from Ywama Power Station, and one 11/33 kV transformer of 30 MVA for the gas turbine generator shall be newly provided because the existing transformer is aged. The secondary circuits of both the generators shall be connected to the 33 kV GIS double bus bar system stated in Section 3.4.3.5.

The **Figure 3.4.3-3** shows the layout of the existing control equipment of the gas turbine and steam turbine and their generators, which will be all relocated to the new control building in Thilawa Power Station.



Source: Prepared by the JICA Study Team from the As-Built Drawings

Figure 3.4.3-3 Existing Layout of Control Room of Ywama Power Station

3.4.3.5 New 33 kV Switchgear in Thilawa Power Station and Extension of 230 kV Switchgear in Thilawa Substation

All the secondary circuit of 11/33 kV transformers of the additional generators as stated below shall be connected to the 33 kV double bus system which shall be newly provided in the control building which shall also be newly built in the Thilawa Power Station. The new 33 kV busbar system shall be independent to the existing (under construction) 33 kV switchgear, which shall be interconnected where necessary to reduce the short circuit current.

1) Generator (23.2 MW) for gas turbine from Ywama Power Station
2) Generator (9 MW) for steam turbine from Ywama Power Station
3) Generator (25 MW) for steam turbine to be added to the existing two gas turbines of Thilawa Power Station

One bay for transformer shall be extended next to the existing bus coupler bay of the existing 230 kV outdoor switchyard, and one new 230/33 kV, 100 MVA three phase transformer shall be installed. The 33 kV bus bar system shall be connected to the secondary circuit of the transformer.

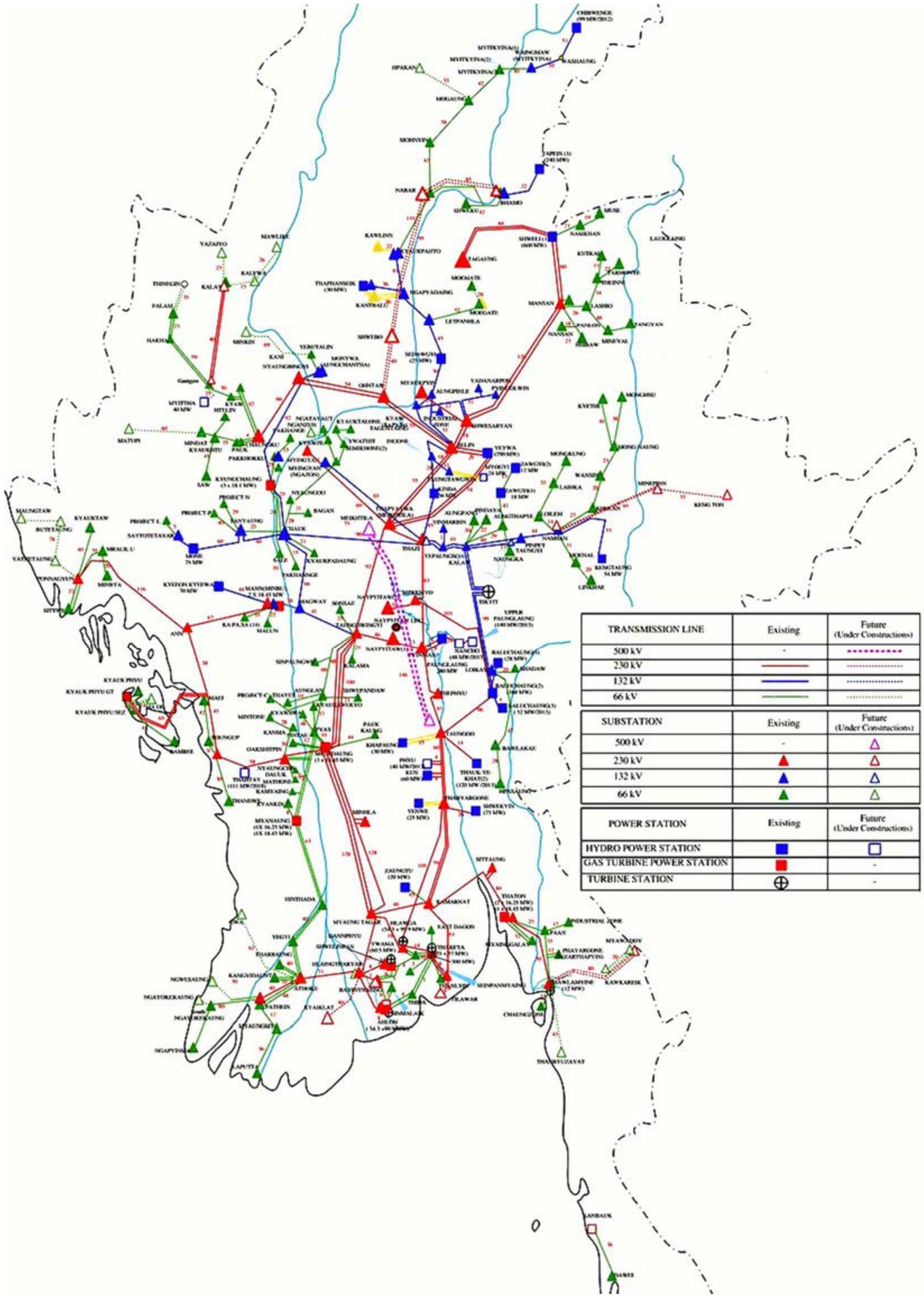
Equipment of 230 kV switchgear necessary for transformer bay for connecting to the existing 230 kV double bus bar system shall be newly provided.

3.4.4 Power Transmission System (including System Analysis)

3.4.4.1 Existing Power Network and Development Plan

(1) Power Network in Myanmar and Yangon City

Figure 3.4.4-1 shows the present and under construction transmission system in Myanmar as of 2017. The voltage systems applied in Myanmar are 230 kV, 132 kV, and 66 kV, and the network system is under the control of the Department of Project Transmission and System Control (DPTSC).

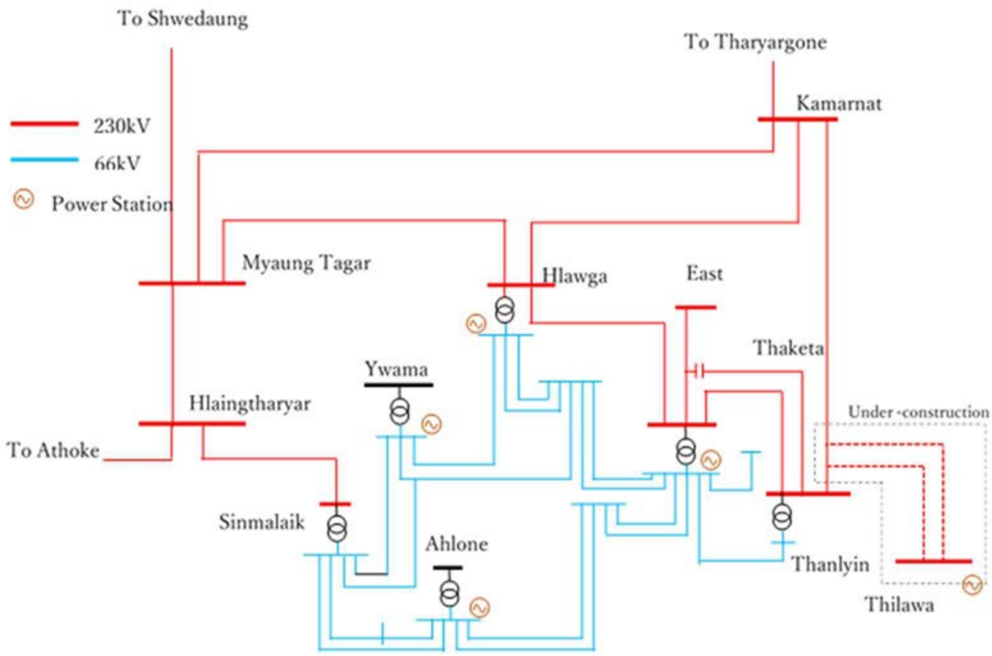


Source: DPTSC

Figure 3.4.4-1 Present and Under Construction Transmission Line Network in Myanmar as of 2017

Myanmar has rich water power resources but most of them are generally concentrated in the central and northern regions. The load center of Yangon City is receiving hydropower from the central and northern regions through 230 kV transmission lines. Not only receiving power from the northern regions, Yangon City is also self-supporting its power demand through four major thermal power plants, namely: Hlawga Power Station, Thaketa Power Station, Ywama Power Station, and Ahlone Power Station, which are located in the city center.

These thermal power stations are connected on the 66 kV and 230 kV transmission line systems controlled by DPTSC. The latest 230 kV and 66 kV system in Yangon City is shown in **Figure 3.4.4-2**.



Source: Prepared by the JICA Study Team based on the data of DPTSC

Figure 3.4.4-2 Present and Under Construction 230/66 kV Transmission Line Network in Yangon

(2) Existing and Under Construction Power System in the Project Area

The Thilawa Special Economic Zone (SEZ) is now receiving power from the Thilawa Power Station, which has two gas turbine generators of 25 MW, and from the Thanlyin Substation, which is 13 km from the MJTD office, through two routes of 33 kV single circuit distribution lines. Each 33 kV distribution line has the 150 mm^2 ACSR conductor, which has a maximum power transmission capacity of 24 MVA.

The new 230/33 kV Thilawa Substation, which is located next to the Thilawa Power Station, and the 230 kV transmission line, connecting the substation to the national 230 kV power grid, are now under construction to meet the increasing demand of the SEZ.

The under construction Thilawa Substation has 230 kV double bus system outdoor conventional type switchyard, with three transformer bays, two outgoing feeder bays, and bus-coupler bays, and 33 kV indoor type GIS switchgears.

Three sets of 230/33/11 kV transformers of 100 MVA are installed to meet the expected maximum demand of 180 MW including additional one set for n-1 criteria. Each transformer has on-load-tap-changing facilities of 260.36 kV as maximum, and 199.64 kV as minimum with 1.65% interval, which is suitable for both sending and receiving end.

The generators in Thilawa Power Station, distribution line from Thanlyin, outgoing feeders for SEZ, and public supply feeders are connected to the 33 kV GIS switchgear, which is connected to the secondary circuit of the transformers.

The under construction transmission line consists of the steel pole supported two circuit configuration, having double bundled conductor of ACSR DUCK (307 mm^2). The maximum transmission capacity per circuit is 410 MVA under the maximum temperature of 75 ºC. Both the circuits of the under construction transmission line are connected to the 230 kV outdoor switchyard of the new Thilawa Substation, and another end will be directly PI-connected to the existing single circuit 230 kV Thanlyin-Kamarnat transmission line, at about 2 km from the Thanlyin Substation. The distance of Thanlyin Substation to Kamarnat Substation is about 98 km. Therefore, one circuit of the under construction transmission line will connect Thilawa Substation to Kamarnat Substation, and another circuit will connect Thilawa Substation to Thanlyin Substation.

The existing Thanlyin-Kamarnat transmission line is of the latticed tower supported single circuit configuration, and has double-bundled conductor of ACSR DUCK (307 mm^2). The maximum transmission capacity per circuit is 410 MVA under 75 ºC operation.

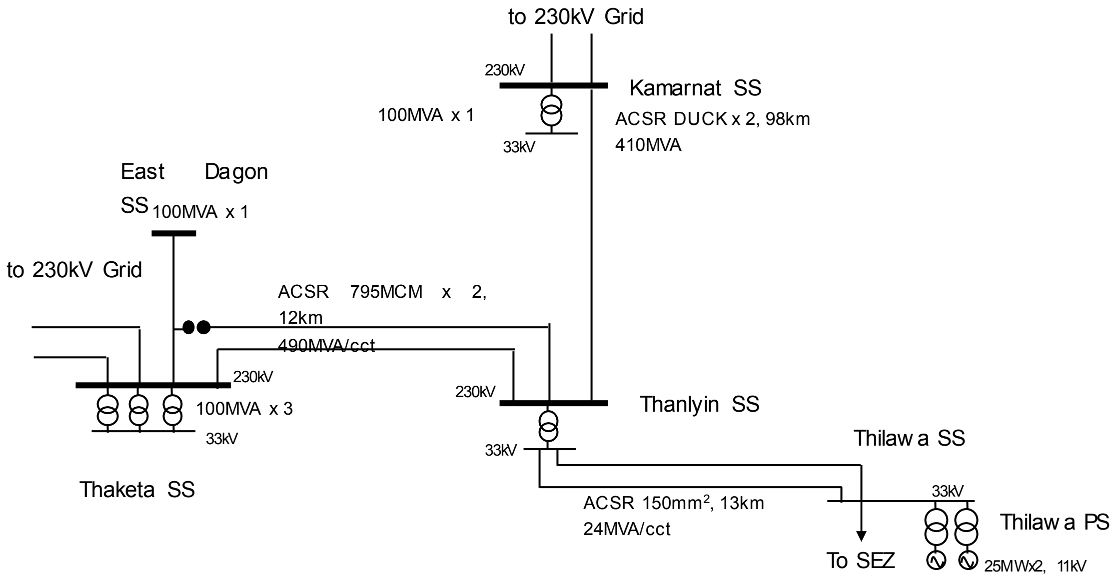
The Thanlyin Substation is connected to the Thaketa Substation in the Yangon City area by the existing 230 kV transmission line of latticed tower supported double circuit configuration, having double bundled conductor of ACSR 795 MCM (402 mm^2). The maximum transmission capacity per circuit is 490 MVA under 75 ºC operation.

The total distance of the 230 kV Thanlyin-Thaketa transmission line is 12 km, including Bago River crossing part of about 2.4 km. Although the line has two circuits configuration, one circuit is not used at present because one of the feeder bays of Thaketa Substation for Thanlyin Substation is now temporarily connected to the newly constructed 230kV transmission line for East Dagon Substation. Two circuit operation of the 230 kV Thanlyin-Thaketa transmission line will be resumed as soon as Thaketa Substation will be renovated.

The system connection statuses before and after completion of Thilawa Substation are shown in **Figure 3.4.4-4** and **Figure 3.4.4-5**.

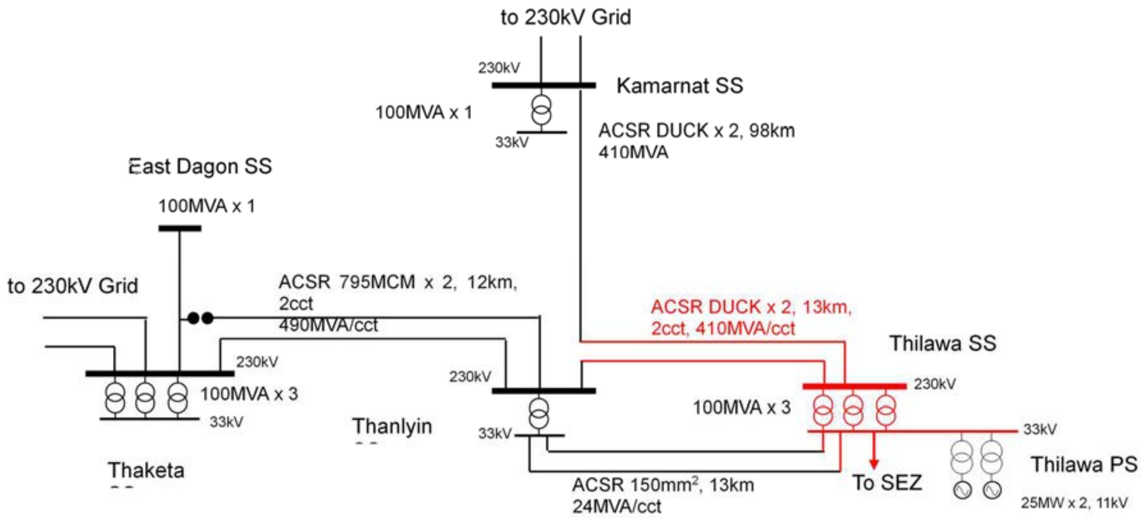
Source: Prepared by the JICA Study Team

Figure 3.4.4-3 230 kV Transmission Line from Thilawa Substation



Source: Prepared by the JICA Study Team

Figure 3.4.4-4 Present Power System for Sending Power to Thilawa SEZ

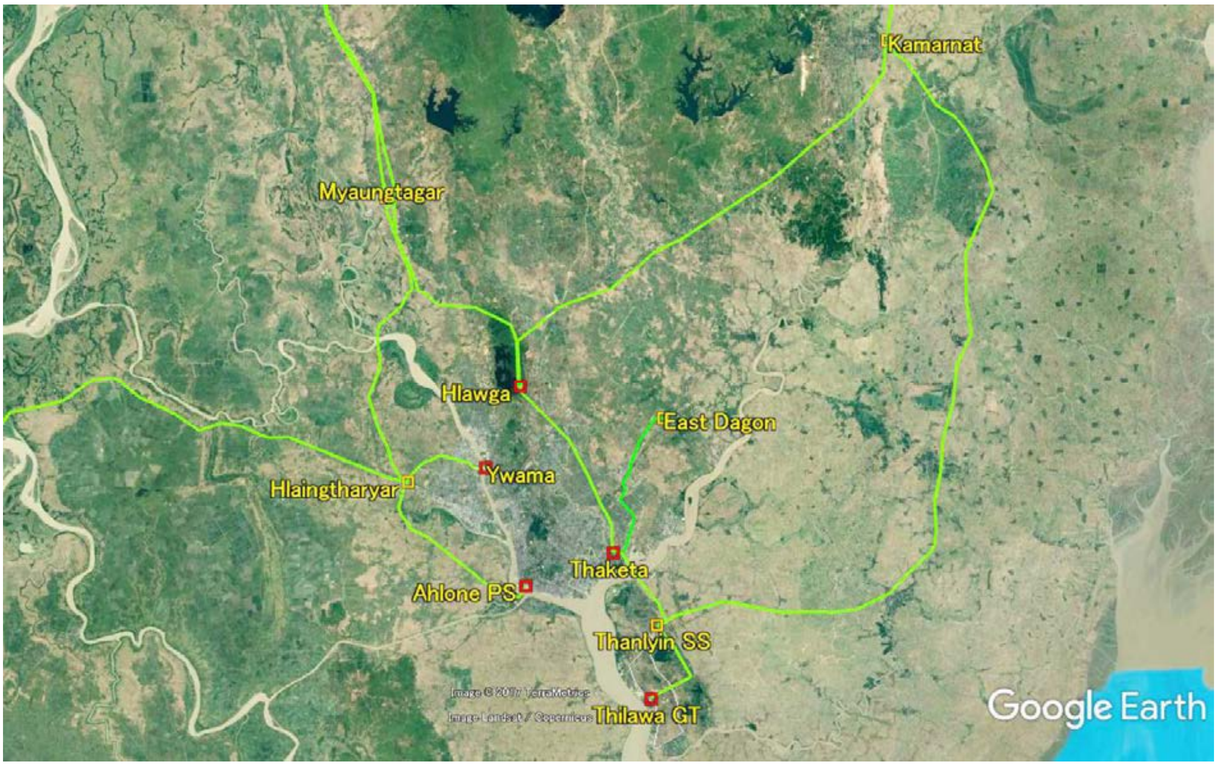


Source: Prepared by the JICA Study Team

Figure 3.4.4-5 Power System for Sending Power to Thilawa SEZ after Completion of Thilawa Substation in 2017

As shown in **Figure 3.4.4-6**, the Thilawa Power Station and Thilawa SEZ will have firm connection to the 230 kV national grid through the under construction 230 kV transmission line through Thaketa Substation (through Thanlyin) and Kamarnat Substation.

When the Thilawa Power Station is repowered by installing combined steam turbine on the existing gas turbines, and replacing the existing power plant from Ywama Power Station to Thilawa Power Station, the increased generated power will be supplied to the bulk consumers in the SEZ and the redundant power will fill up the power shortage in Yangon. The maximum redundancy will occur when the factories in the SEZ reduces their power consumption at night or on holidays. The existing power system, including the under construction Thilawa Substation and 230 kV transmission line, has enough capacity to receive full expected demand of 180 MW from the national power grid, and to send the full generating capacity of Thilawa Power Station.



Source: Prepared by the JICA Study Team

Figure 3.4.4-6 Geographical Location of 230 kV Network System Connecting to Thilawa Substation

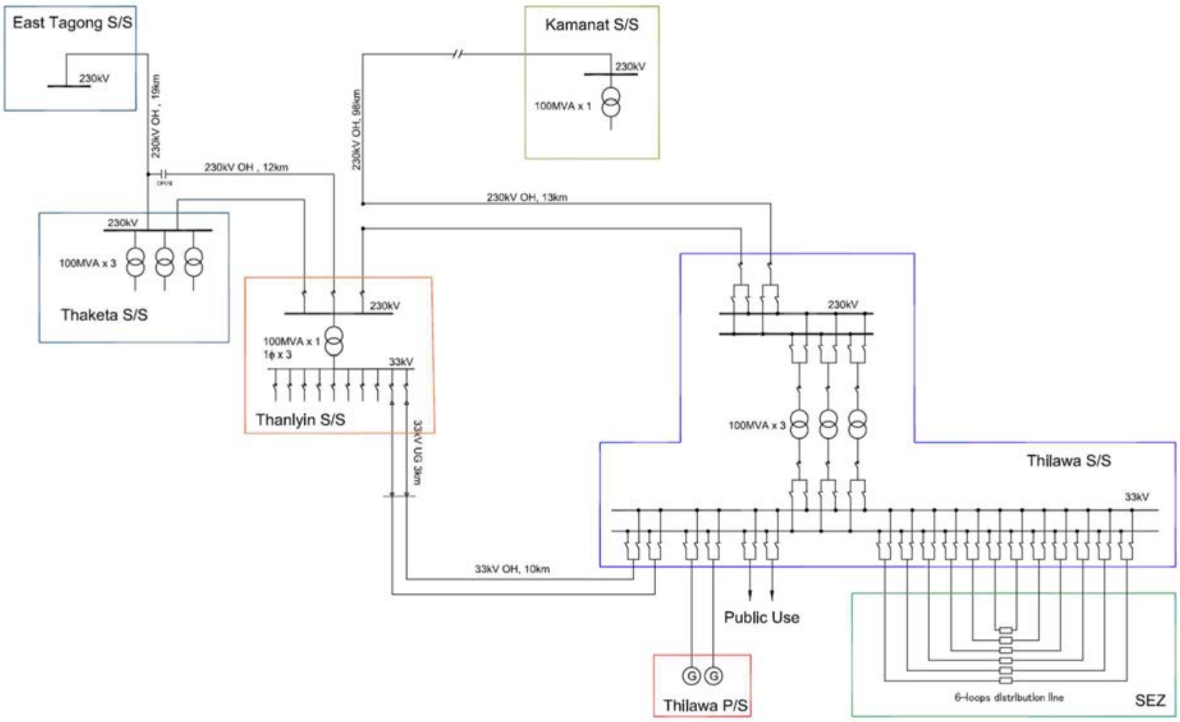
The 33 kV double bus bar system of the under construction Thilawa Substation will have the following feeders:

- 3 feeders for 100 MVA transformer
- 2 feeders for Thilawa gas turbine generators
- 2 feeders for existing 33 kV distribution lines from Thanlyin Substation
- 12 feeders for 6-loops distribution system for SEZ
- 2 feeders for public power supply

The rated short circuit current of the circuit breakers of each feeder is designed as 40 kA, and the rated current of the bus is 2,500 A.

After Thilawa Substation is completed, 12 feeders are to be provided for six loops distribution line system in the SEZ. MJTD, the owner of the SEZ, is the consumer who receives the 33 kV power at the output terminal of the 33 kV switchgear in Thilawa Substation. The MJTD will own and maintain the facilities of the six loop type distribution line system.

Figure 3.4.4-7 shows the connection status after the Thilawa Substation is completed.



Note: Demand at Thilawa SEZ shall be examined at the timing of extension of existing panel.
Source: Prepared by the JICA Study Team

Figure 3.4.4-7 Network System of Thilawa Substation and Surroundings

(3) Development of Power System for the Project

Recently, MJTD requested DPTSC to extend six more feeders for additional three loops of distribution line system to provide power to the cement factory which will be a new tenant of the SEZ. DPTSC is examining their proposal and their proposal is going to be accepted, and the bus capacity will be increased from 2,500 A to 5,000 A.

When Thilawa Power Station is repowered by installing combined steam turbine on the existing gas turbines and relocation of power plants from Ywama Power Station, the following three additional generators shall be connected to the independent 33 kV bus bar system to avoid increase of short circuit current of the existing 33 kV bus system:

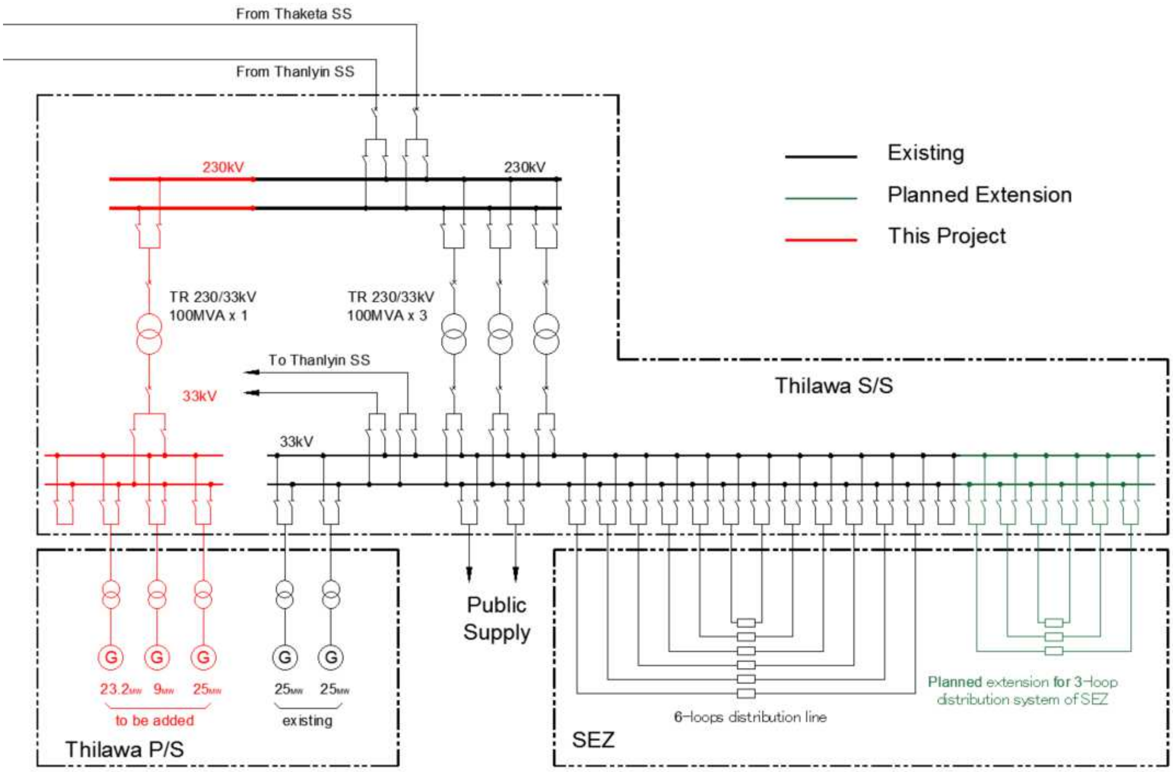
- Generator (23.2 MW) for gas turbine from Ywama Power Station
- Generator (9 MW) for steam turbine from Ywama Power Station
- Generator (25 MW) for steam turbine to be added to the existing two gas turbines of Thilawa Power Station

The output voltage, 11kV, of the above three generators shall be stepped up to 33 kV by the 11/33 kV transformers of 11 MVA, 30 MVA, and 30 MVA, respectively, and shall be connected to the double bus system of the 33 kV switchgear to be newly provided. The existing transformer of the gas turbine generator in Ywama Power Station is old for reuse, but that of the steam turbine generator shall be reused. Therefore, new 11/33 kV transformers for gas turbine from Ywama and for steam turbine to be added to Thilawa gas turbines shall be provided newly.

One 100 MVA transformer equipped with auto-tap-changing facilities of 260.36 kV (max.) and 199.64 kV (min.) with 1.65% interval and the outdoor 230 kV switching gear for the transformer bay shall be provided next to the existing bus coupler bay of Thilawa Substation. The above 33 kV double bus system shall be connected to the secondary circuit of the above transformer.

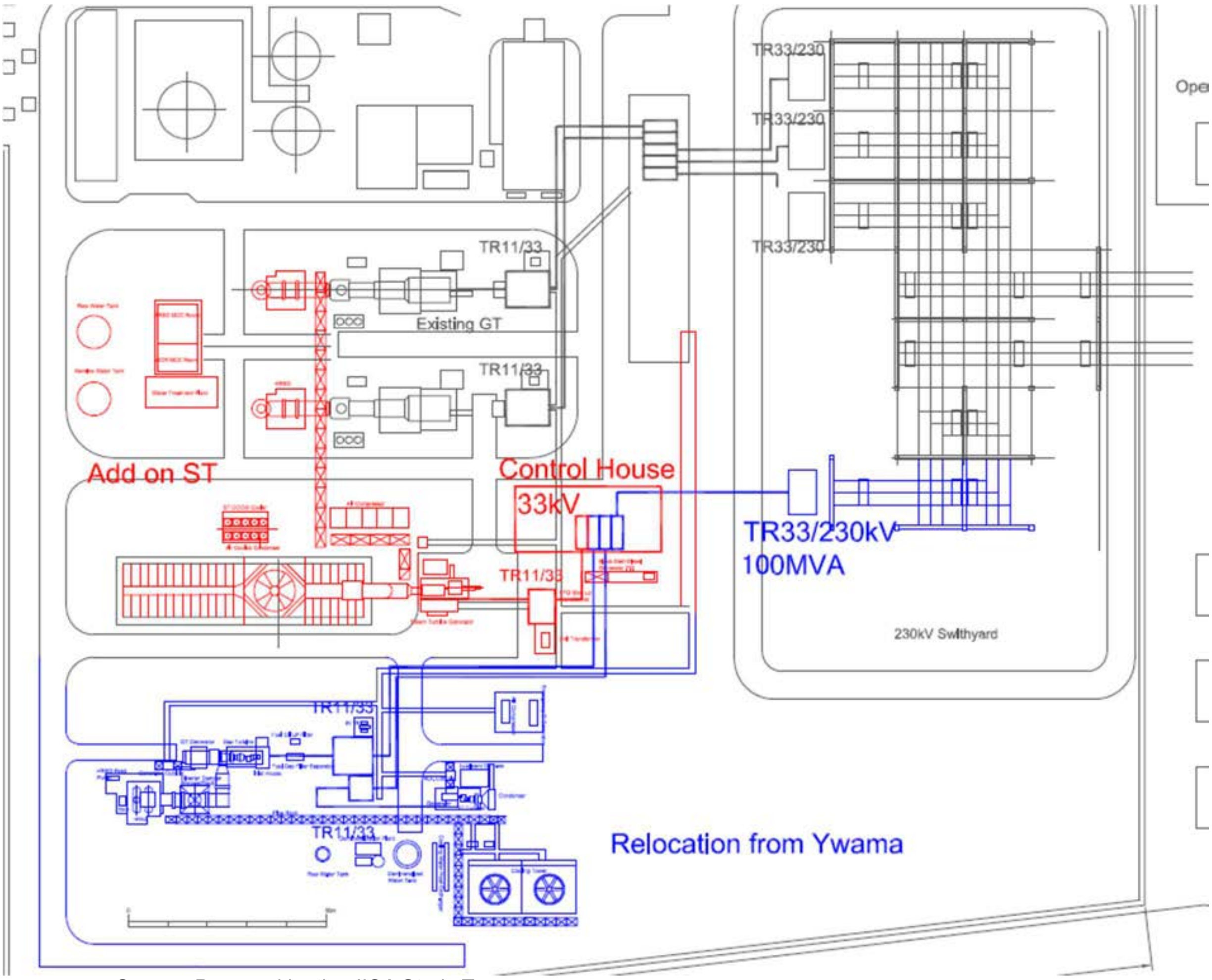
The newly provided 33 kV switchgear shall be installed in the control building to be newly built. All the panels necessary for power source, control and communication to be installed newly and relocated from the Ywama Power Station shall be installed in the newly built control building.

The connection method and schematic layout of the electrical equipment of Thilawa Power Station and Substation are shown in **Figure 3.4.4-8** and **Figure 3.4.4-9**.



Source: Prepared by the JICA Study Team

Figure 3.4.4-8 Network System of Thilawa Substation when Thilawa Power Station is Repowered

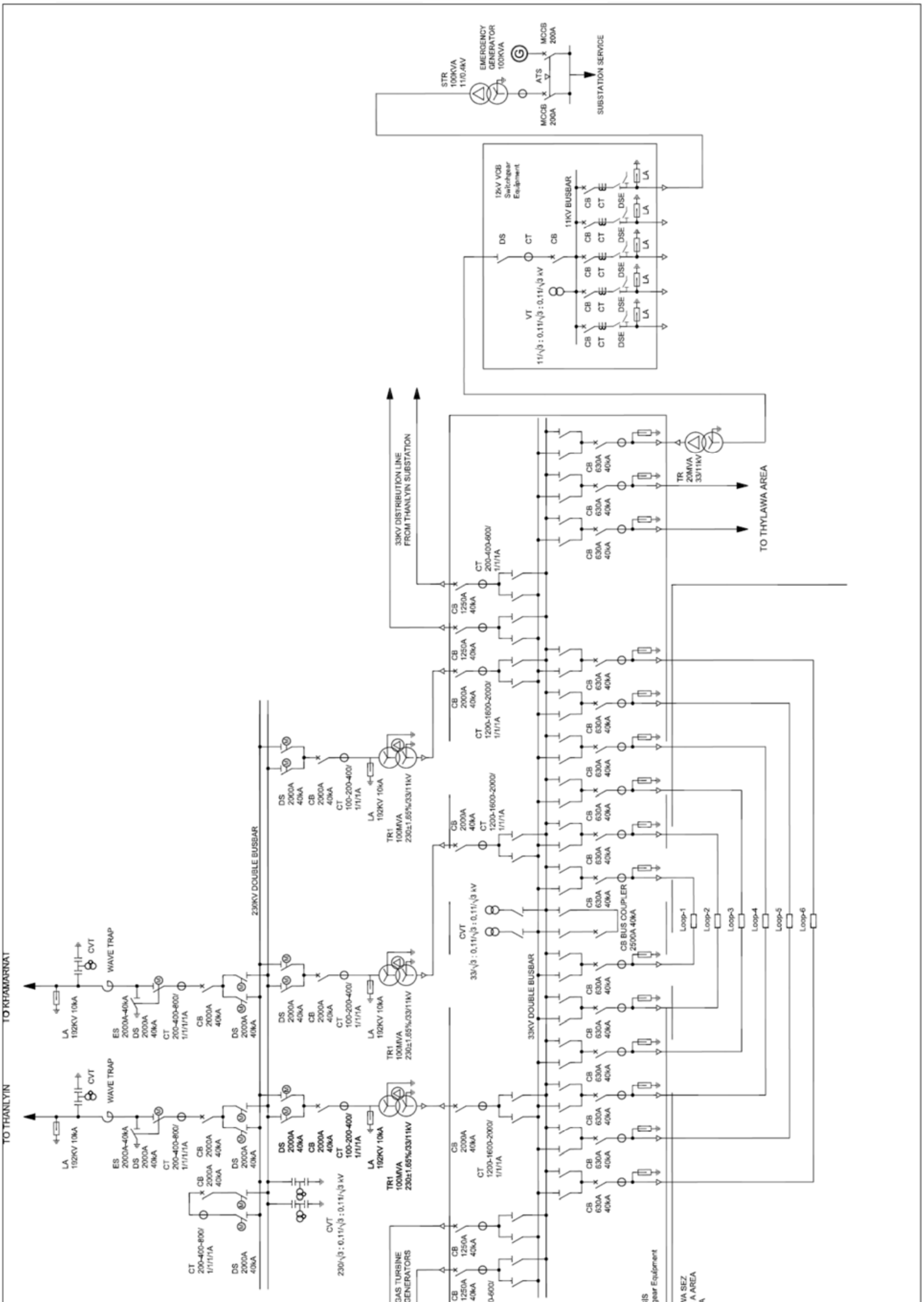


Source: Prepared by the JICA Study Team

Figure 3.4.4-9 Schematic Layout of Thilawa Power Station and Substation

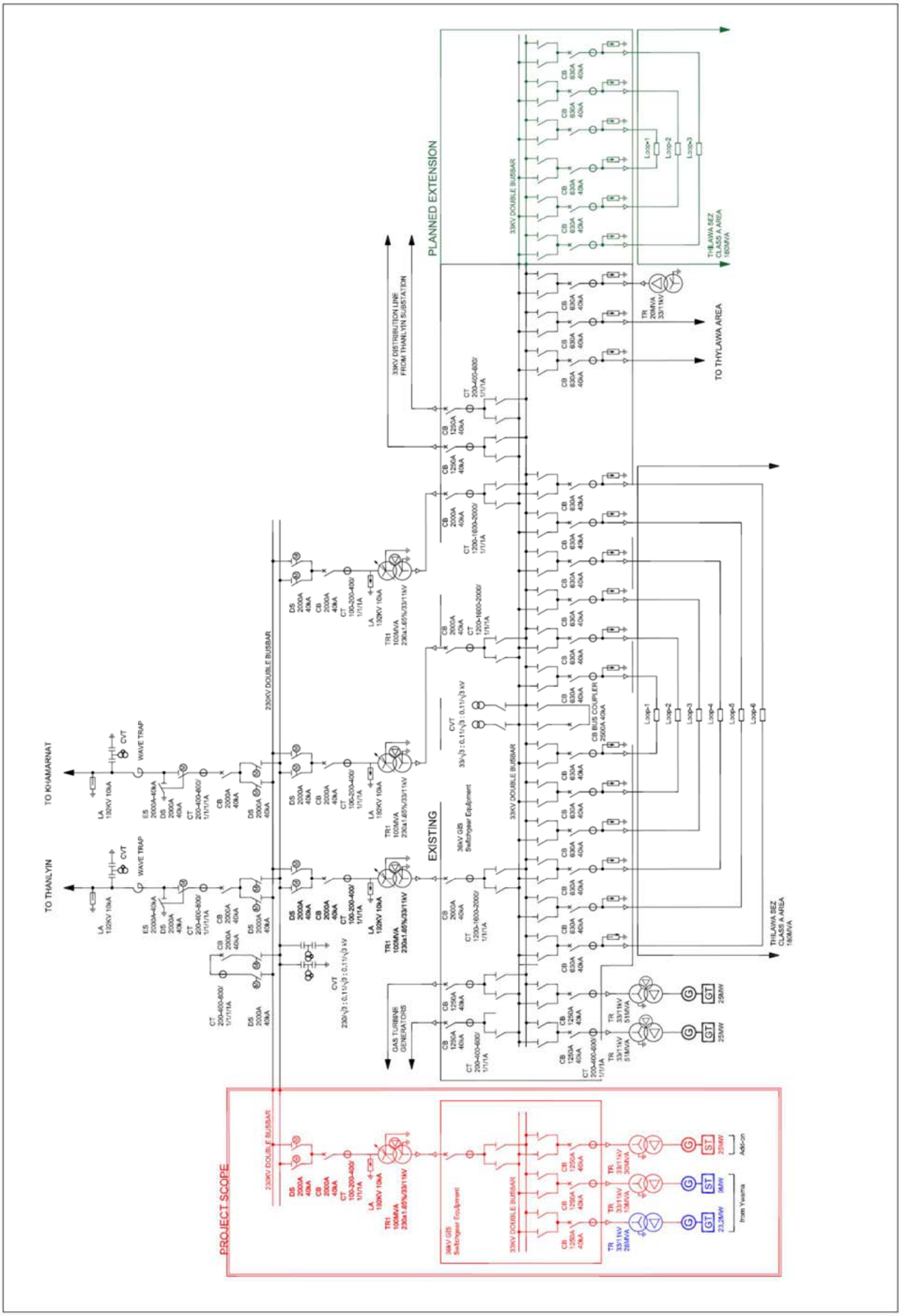
The **Figure 3.4.4-10** and **Figure 3.4.4-11** show the single line diagrams of Thilawa Substation, as of the completion of the construction expected in the beginning of 2018 and as of completion of the repowering of Thilawa Power Station and replacement of plants from Ywama Power Station respectively.

Figure 3.4.4-12 shows the five-year plan of the power system in Myanmar, made by DPTSC in 2017.



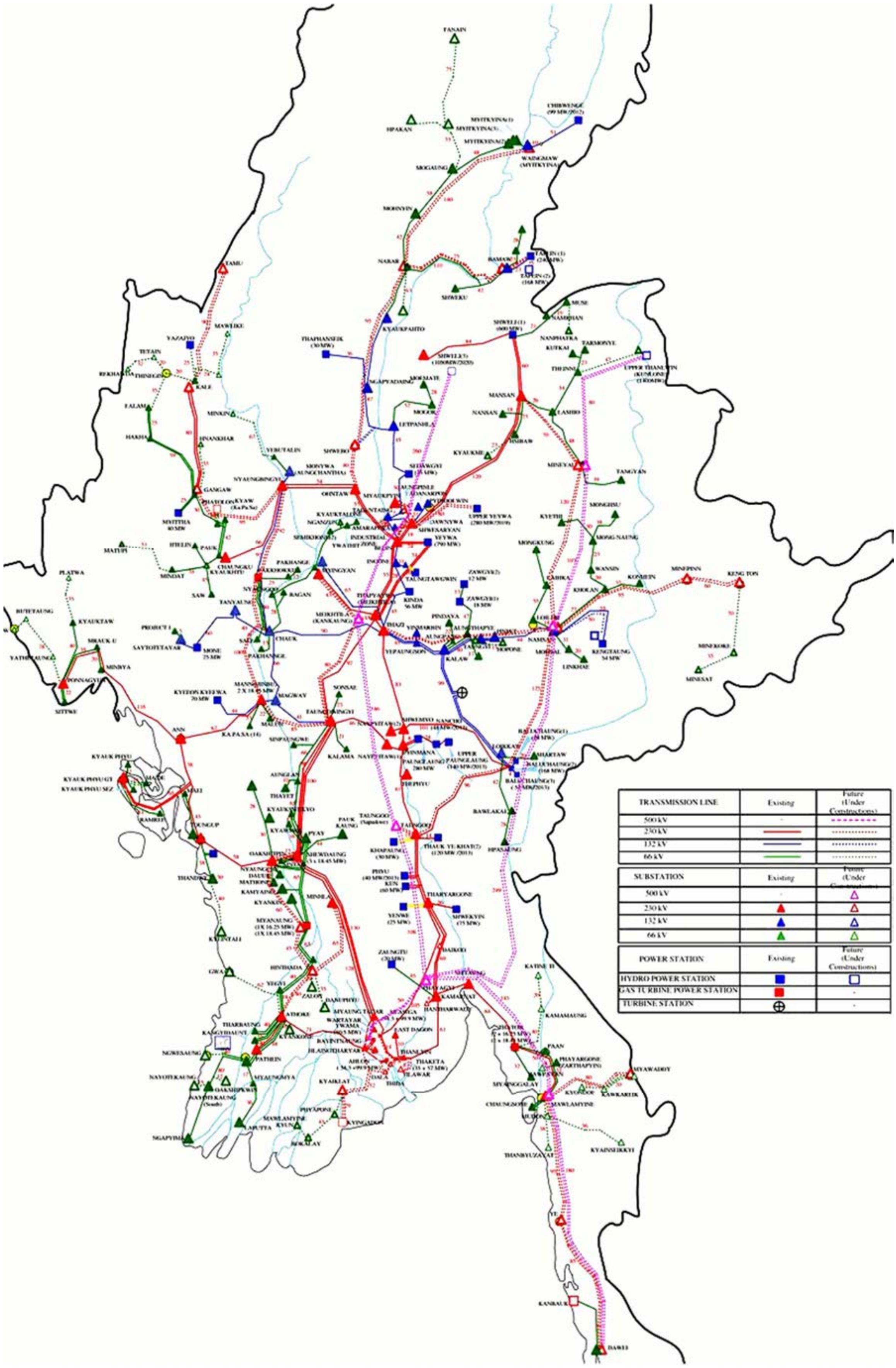
Source: Prepared by the JICA Study Team based on Interview with Relevant Organizations

Figure 3.4.4-10 Single Line Diagram of Thilawa Substation



Source: Prepared by the JICA Study Team based on Interview with Relevant Organizations

Figure 3.4.4-11 Single Line Diagram of Thilawa Substation after Repowering



Source: DPTSC

Figure 3.4.4-12 Five-year Plan of the Power System in Myanmar, Made by DPTSC in 2017

(4) Requirements of Transmission Line and Substation Equipment for Repowering

The existing and under construction transmission line and distribution line facilities have enough current carrying capacity to send the power generated by repowered plants, and no additional transmission lines or distribution lines are necessary.

The existing and under construction substation have enough capability to send the power generated by repowered plants, and no additional substation equipment is necessary except:

- 11/33 kV step-up transformer for add-on steam turbine generator
- 11/33 kV step-up transformer for gas turbine generator from Ywama Power Station
- 33/230 kV 100 MVA three phase transformer with on-load-tap-changing facilities of 260.36 kV (max.) and 199.64 kV (min.) with 1.65% interval which is suitable for both sending and receiving end
- 230 kV switching facilities, including surge arrester, disconnecting switches, circuit breaker, current transformers, and steel structures for transformer bay to be extended next to the existing bus coupler bay
- 33 kV double bus system cubicles for three generator circuits, one 230/33 kV transformer circuit, and one bus coupler, suitable for full-load with rated short circuit current of 40 kA
- Control panels, relay panels, battery and charger, etc. for 230 kV and 33 kV switchgear
- Control building capable to install control panels, relay panels, battery and charger for 230 kV and 33 kV switchgear, 33 kV cubicles, control panels and switchgears of add-on steam turbines and generators, and all the control and switchgears relocated from Ywama Power Station
- Expansion of road and cable ducts
- Modification of existing facilities, if necessary

3.4.4.2 Evaluation of Project's Impact to the Power System

From the viewpoint of the whole Myanmar power system in which Thilawa Power Station is included, the additional power capacity of projects, which is expected to be 57.2 MW after repowering, is relatively low and connected to lower level 33 kV power system. So, the effect of projects to the whole Myanmar power system is slight and seemed to cause no severe problem to the whole Myanmar power system as mentioned below.

However, affection on the nearby power system related to the project should be evaluated based on the power system analysis utilizing PSSE software.

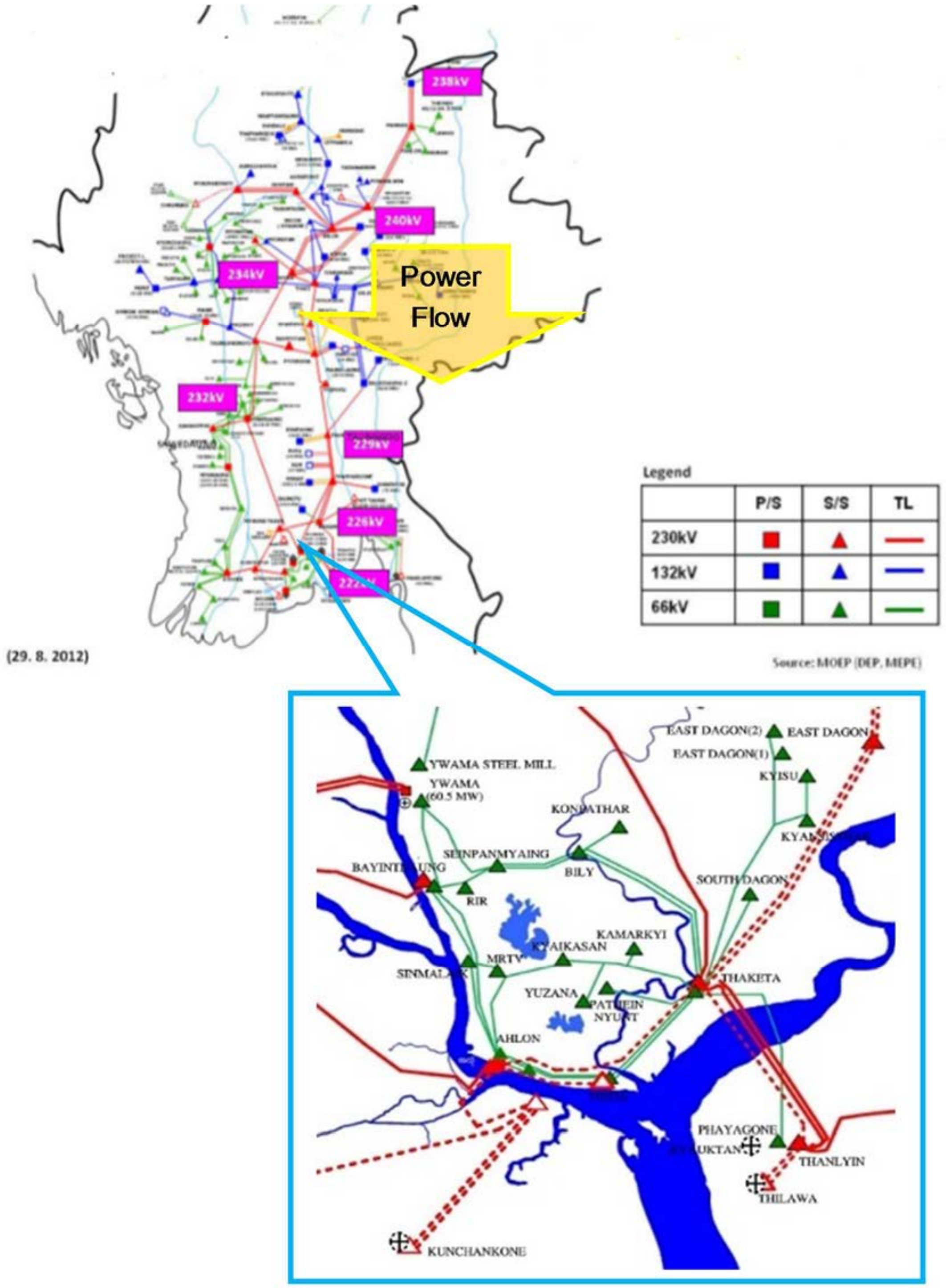
Before analyzing, basic precondition and assumptions are arranged as described below for evaluation purpose.

(1) Main Characteristics of Myanmar Power System

The outline of the power system in Myanmar is shown in **Figure 3.4.4-13**. Thilawa Power Station is located in the southern load center of Myanmar Power System near Yangon City.

In general, as mentioned previously, the main power flow of trunk lines of the Myanmar system seems to flow from the northern area, where many main hydropower stations are located, to the southern area, where heavy load area is located such as Yangon City and special economic zone areas. The electric power of the trunk transmission of the whole Myanmar power system flows from the northern side to the southern side.

After this repowering project was commissioned, this trunk transmission power flow will be deduced, which is preferable from the system stability viewpoint. So after this project, the power flow restriction from the north side would be lessened.



Source: Prepared by the JICA Study Team based on the map provided by DPTSC

Figure 3.4.4-13 Outline of the Myanmar Power System and the Current Diagram of the System of Thilawa Power Station

(a) Additional Power Magnitude of Thilawa Power Station

Thilawa Power Station now consists of GTG open cycle gas turbine plants (25 MW x 2 units).

Through the repowering of the Thilawa Power Station by changing the existing GTG open cycle into combined cycle and by adding another GTG relocated from Ywama Power Station, the additional power magnitude seems to be 57.2 MW in case of Option 4 plan.

(b) Affection of the Project on the Whole Myanmar Power System

Under the current situation of the whole Myanmar Power System mentioned above, the repowering or development of the power plants located in the southern area seems to be preferable from the viewpoint of power system stability or power supply reliability. In particular, thermal type generation in the vicinity of the sea or river in the southern area seems to be more suitable for providing stable power to the grid throughout the year.

In consideration of these circumstances, the repowering of Thilawa Power Station located in the southern side or near the load center of the Myanmar system is suitable from the viewpoint of stable power supply. In other words, the additional power of 57.2 MW in Thilawa Power Station seems to contribute to reduce the existing 230 kV trunk power flow of the whole Myanmar system toward the southern direction. Moreover, the additional power supply of 57.2 MW in Thilawa Power Station is relatively small compared with the trunk power flow level of around 1,000 MW or over. Therefore, it seems not necessary to consider the effect of this additional power (57.2 MW) to the whole Myanmar system from the power system reliability viewpoint mentioned before. On the contrary, it is required to clarify the effect of the repowering of Thilawa Power Plant and the system problem in the vicinity system of Thilawa Power Station including Yangon area.

Accordingly, evaluation of the affection of the repowering of Thilawa Power Station was conducted for the local power system that is composed of 33 kV and 230 kV system in the vicinity system of Thilawa Power Station including Yangon area [hereafter referred to as the local power system] through the following steps:

(2) Evaluation of the Affection of the Project on the Power System

As mentioned above, the evaluation method of the project's affection on the power system was conducted on the local power system including Thilawa Power Station and Yangon area from the following main aspects. System stability analysis is performed based on data and information provided by DPTSC.

(a) Current situation of the local power system

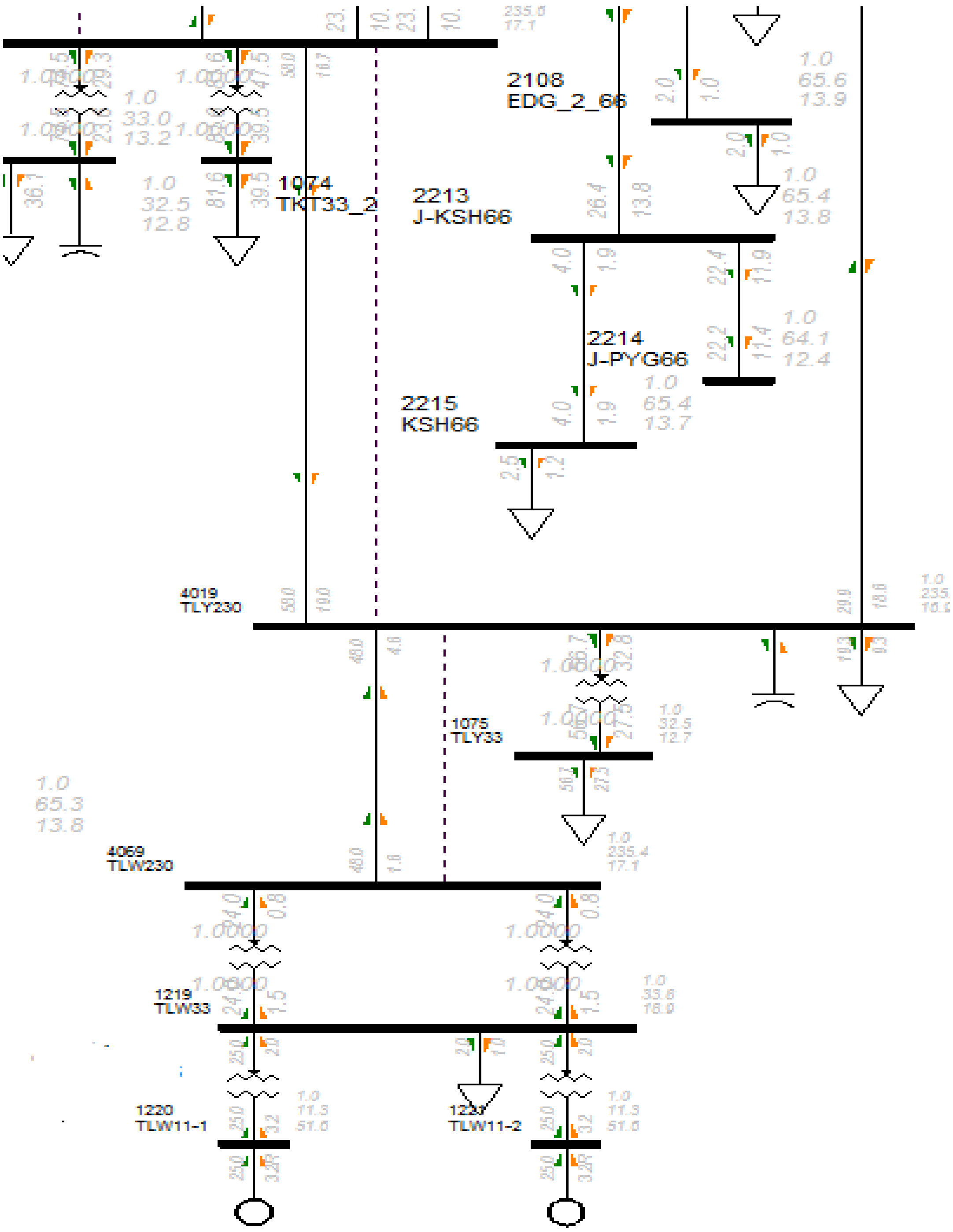
The Thilawa Power Station is connected to Thaketa Substation via Thanlyin Substation by 230 kV transmission line.

The produced power from the Thilawa Power Station is supplied mainly to Thilawa SEZ and the surplus power is supplied to Yangon area after raising the voltage to 230 kV through the step-up transformer in Thanlyin Substation as well.

The power flow of the related grid system is basically directed to Thanlyin at peak time currently as shown in **Figure 3.4.4-14**.

The sending capacity of 230 kV trunk lines remains under 410 to 490 MW even though if any 230 kV transmission line is out of service due to maintenance or accident.

Therefore, there seems to be no problem from the system operation viewpoint. It seems it is not required to install additional 230 kV transmission line in accordance with the repowering of Thilawa Power Station, which will be verified by simulation in this study as well.



Source: Prepared by the JICA Study Team

Figure 3.4.4-14 Power Flow of Related Grid System Near Thilawa and Yangon

<u>(b) System review from the local power system related to the project</u>

The repowering power of Thilawa Power Station will be connected to 33 kV bus directly. The total capacity after repowering is expected to reach 107.2 MW which is a relatively large capacity in the local power system. Thus, the issues of power flow and short circuit capacity aspect were considered in the local power system with planned reinforcement hereafter.

According to the Power Development Plan in the local power system, the following main changes are planned in the future:

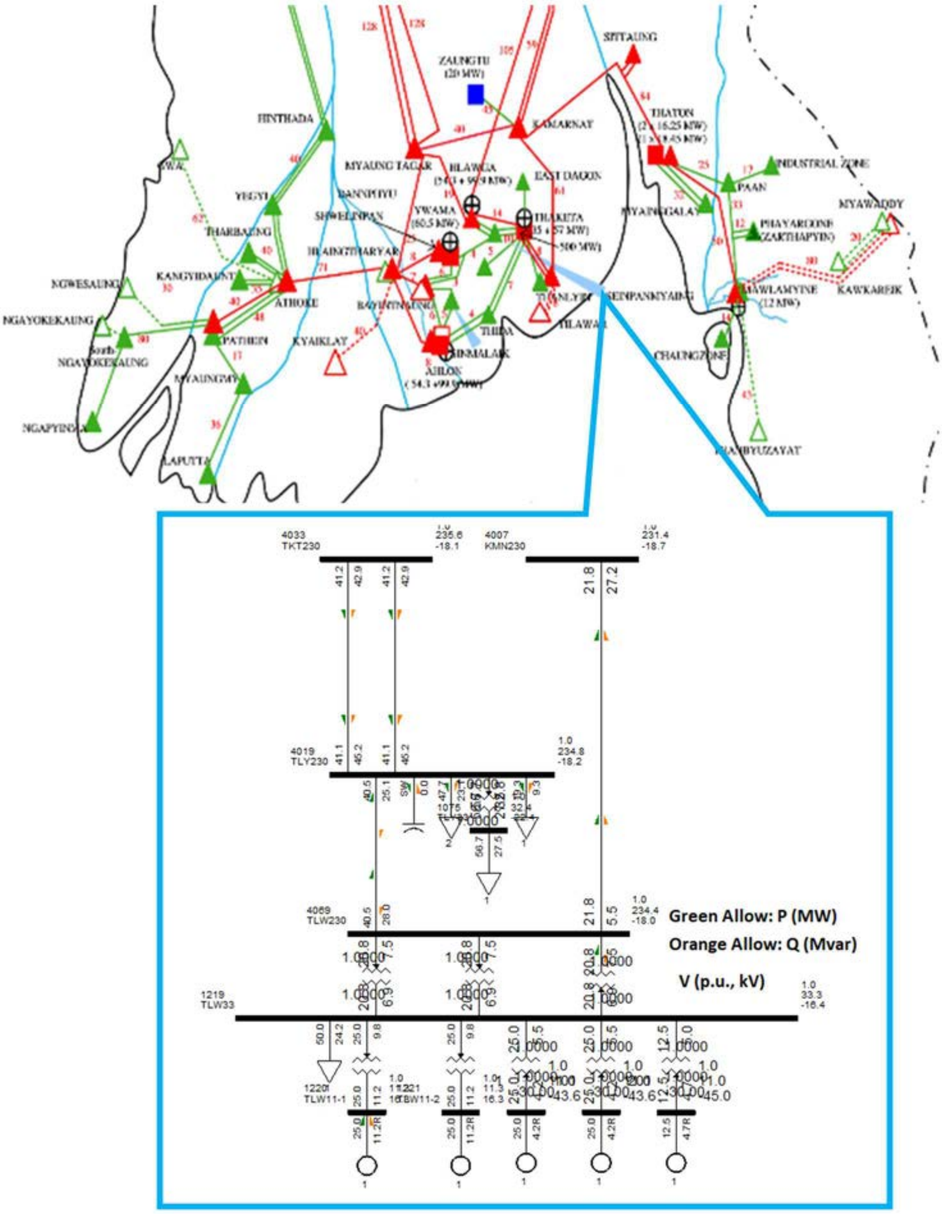
- 230 kV transmission line with one circuit will be planned between Thilawa Substation and Kamarnat Substation
- Two circuits of 230 kV transmission between Thanlyin Substation and Thaketa Substation will be connected in the near future although only one circuit is operated currently.
- 230 kV transmission line with one circuit will be planned between Thanlyin Substation and Thilawa Substation.

Regarding the local power system of this project, the affection and restriction were evaluated considering the reinforcement plan.

On the other hand, regarding the system configuration of Thilawa Power Station, STG and GTG to be attached by repowering is planned to be connected to 33 kV bus with reinforcement of related step up transformer.

After that, 33 kV bus is connected to the 230 kV power system through the related transformer (230/33 kV, 300 MVA) with on-load tap changer equipment and operated as loop system.

The planned single line diagram of Thilawa Power Station after repowering and the local power system is shown in **Figure 3.4.4-15**.



Source: Prepared by the JICA Study Team based on the map provided by DPTSC

Figure 3.4.4-15 System Configuration for Evaluation

System voltage, power flow, and short circuit current are evaluated hereafter based on the local power system.

In addition, transient stability was also evaluated tenably just for reference as described below.

(c) Criteria for Evaluation of Power System Reliability

In accordance with the above condition, the following points were checked and clarified through the power system analysis and simulation was conducted using PSSE software for evaluating the power system reliability.

a) Criteria for power flow analysis including short circuit current

For the evaluation of the power flow analysis including short circuit current, the following criteria were adopted:

- Sufficient capacity of main components such as conductors and transformers to ensure that power flow does not exceed capacity limits under normal conditions or disturbance situations (N-1 rule)
- Sufficient capacity of reactive compensation equipment, such as shunt reactance and/or capacitance to ensure that voltages at substations, etc. do not exceed voltage limits under normal conditions or disturbance situations (N-1 rule)
- Sufficient capacity of circuit breakers to ensure that short circuit currents do not exceed their capacity, which is normally 40 kA for 33 kV system and 40 kA for 230 kV system, in three-phase short circuit faults, respectively.

b) Criteria for Evaluation of Transient Stability

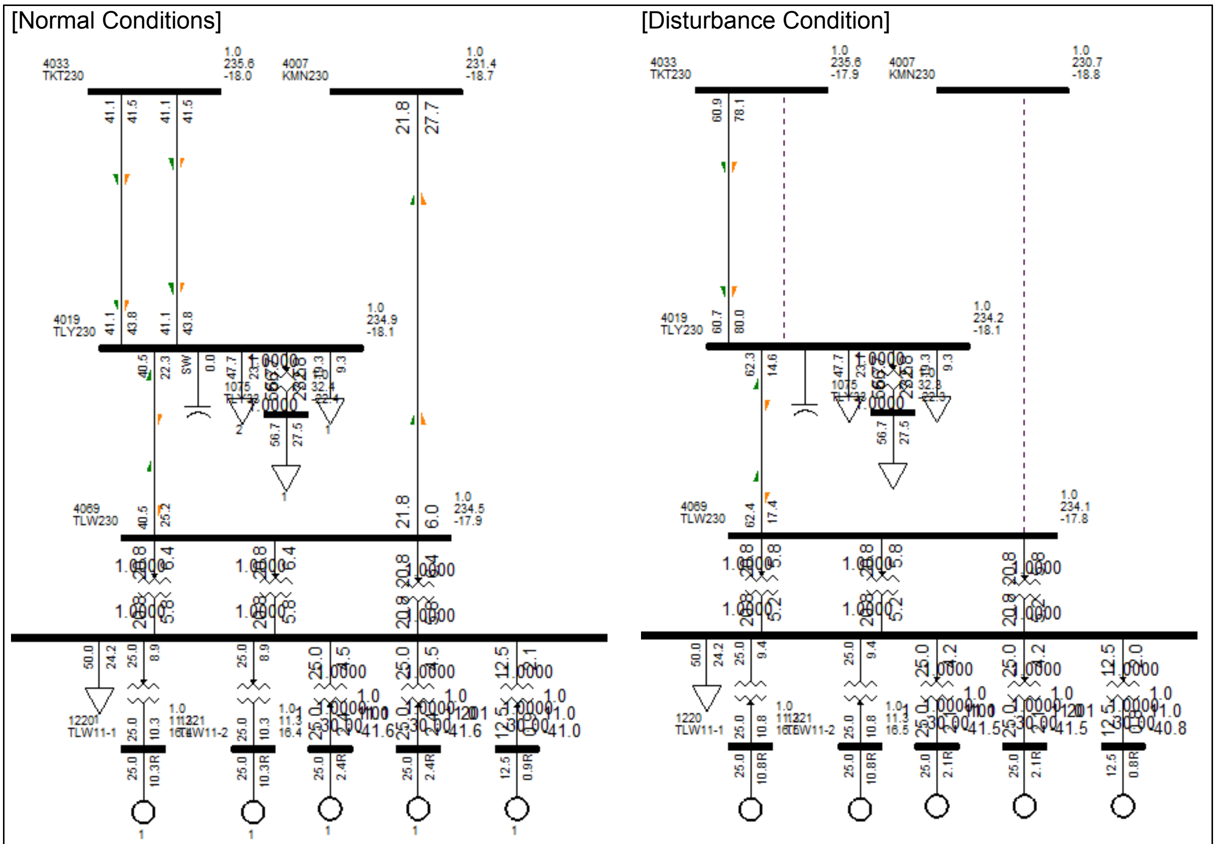
The transient system stability was evaluated to check the performance of related generators under the three-phase grand fault accident of related 230 kV transmission line just for reference based on the following precondition:

a) Assumed Accident	
For checking the transient stability, the following parameters were adopted at the accident in the protected systems:	
- Accident condition	three-phase short circuit accident and one circuit open
- Accident clearance time	100 ms
- Load characteristic	an active power element has constant current characteristic, and a reactive power element has constant impedance
b) Basic Characteristics of Generator	
As for the generator constant, excitation and turbine governor characteristic, the IEEE standard data was used for characteristics of AVR/GOV.	

c) Result of Evaluation of the Local Power System Reliability

The actual evaluation of the power system was conducted in view of the effect to the vicinity power system from the selected plan taking the above situation change into consideration using PSSE as described hereafter.

a) Evaluation of Power Flow Aspect
From the power flow analysis, the following issues were ensured after repowering of Thilawa Power Station and related reinforcement of transmission, etc. as shown in Figure 3.4.4-16. ● Sufficient capacity of main components such as conductors and transformers is kept within the tolerable capacity limits under normal conditions or disturbance situations (N-1 rule) ● Regarding voltage aspects, the 230 kV bus voltage would be kept within regulated bandwidth easily because of 230/33 kV transformer with on-load tap changer and there seems to be no restriction for reactive power operation of the project plant. Based on the result of the abovementioned study, necessary equipment such as shunt reactor or condenser will not be required to be installed in substations of the local power system related to Thilawa Power Station for keeping each level voltage within the restricted band level.



Source: Prepared by the JICA Study Team

Figure 3.4.4-16 Simulation Result of Power Flow under Normal Conditions and Disturbance Situations

b) Evaluation of Short Circuit Capacity

The short circuit was checked based on possible maximum short current of related 33 kV and 230 kV bus under the severe case.

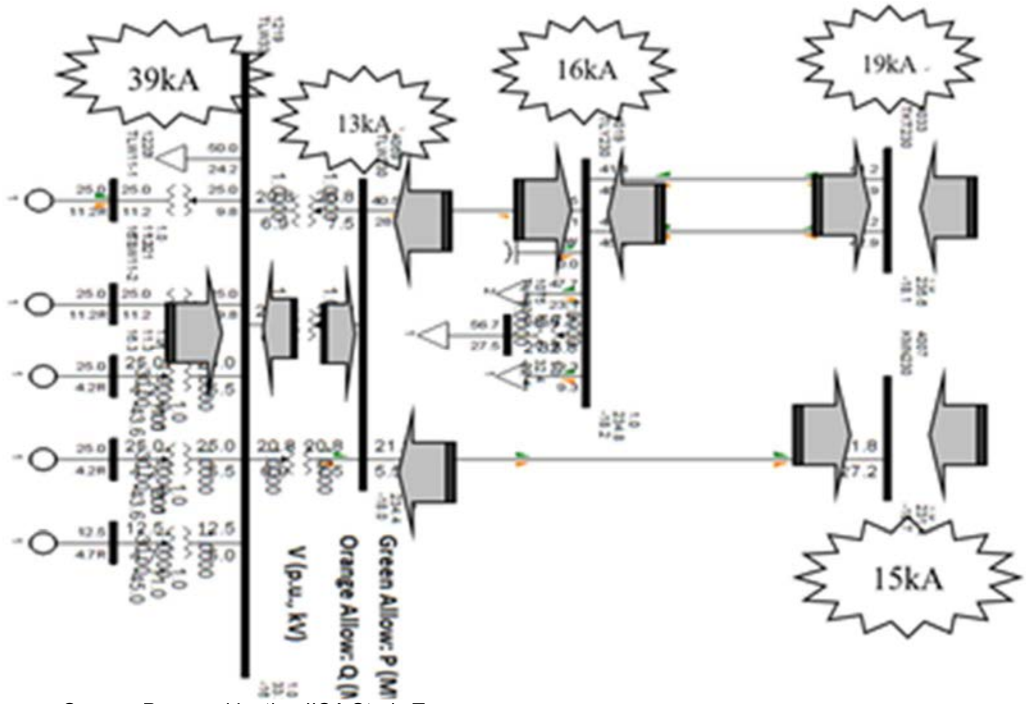
As for the aspect of short circuit capacity, the short circuit capacity of Thilawa Power Station seems be determined mainly by short circuit current flow from Thilawa Power Station itself.

Judging from the result of simulation taking the severe case into consideration, there seems to be no severe problem after repowering of Thilawa Power Station because total short circuit value of 33 kV bus is under 40 kA which is within tolerable capacity for related 33 kV circuit breaker as shown in Figure 3.4.4-17.

However, the circuit breaker level of 33 kV system seems to be very high and approaching the maximum short circuit level. So it is recommended to check again by using exact impedance such as internal impedance of generators and step-up transformer. For reducing the short circuit level of 33kV bus there are some countermeasures such as adaption of high impedance step-up transformer, adaption of high internal impedance generators and change the connection of generators in Thilawa Power Station etc. if required.

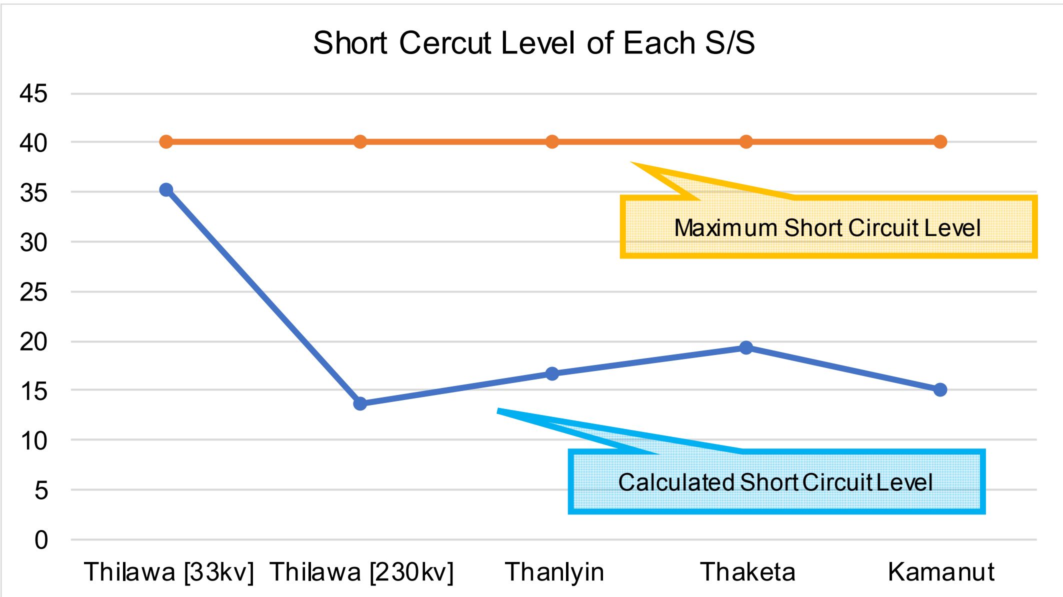
As for the countermeasure of change the connection of generators in Thilawa Power Station instead of adaption of high impedance step-up transformer etc, which require more cost, further study was conducted as described below in close relation with EPGE and DPTSC.

On the other hand, regarding the 230 kV bus, there might be no problem without any countermeasure such as bus separation because short circuit capacity seems to be under 40 kA as shown in Figure 3.4.4-17 including vicinity substations after repowering of Thilawa Power Station as well.



Source: Prepared by the JICA Study Team

Figure 3.4.4-17 Short Circuit Value of 33 kV Bus



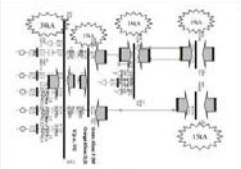
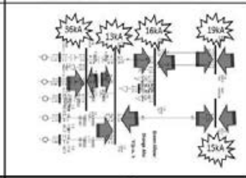
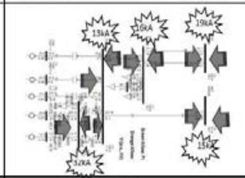
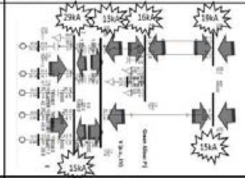
Source: Prepared by the JICA Study Team

Figure 3.4.4-18 Short Circuit Level of Each Substation in Local Power System

a) Tentative Connection Options of Generators in Thilawa Power Station

For reducing the short circuit level of 33 kV bus in Thilawa Power Station of Option 1 as mentioned above, several combinations of connection options of generators in Thilawa Power Station were carried out and comparison of connection combinations was made as shown in Table 3.4.4-1.

Table 3.4.4-1 Comparison of Connection Options of Generators in Thilawa Power Station

Option NO		Option 1	Option 2	Option 3	Option 4
Configulation		All Generators are connected to 33kV Bus	All GTG are connected to 33kV Bus All STG are connected to 230kV Bus	Thilawa GCCT is connected to 230kV Bus GCCT from YWANA is connected to 33kV Bus	Thilawa GCCT is connected to 33kV Bus GCCT from YWANA is connected to 230kV Bus
					
Short Circuit Aspect	Evaluation (Max Current)	▲ (39kA at THILAWA 33kV Bus)	○ (36kA at THILAWA 33kV Bus)	○ (32kA at THILAWA 33kV Bus)	◎ (29kA at THILAWA 33kV Bus)
	Countermeasure	· Adaptopn of High Inpedance to Step-Up Tr of G · Criac Reactol between 33kV Buses or Separation of 33kV Bus	----	----	----
Operation Aspect		◎ (O&M for Both GCCT's are conducted independantly)	○ (Need to adjust O&M between GCCT and two Bus's)	◎ (O&M for Both GCCT's are conducted independantly)	◎ (O&M for Both GCCT's are conducted independantly)
Equipment Aspect (Rough Cost)		◎ (Base:11/33kV Tr*3)	▲ (Addtion: 11/230kV Tr*2 - 11/33kV Tr *2)	▲ (Addtion: 11/230kV Tr*3 - 11/33kV Tr *3)	○ (Addtion: 11/33kV Tr *2)
Total Evaluation		▲	○	○	◎

Source: Prepared by the JICA Study Team

Judging from the following aspects, Option 4 seems to be preferable among the connection options of generators:

- The short circuit current of Thilawa 33 kV bus should be reduced due to almost reaching maximum capacity of CB:
  Option 4 achieves the most reduction of short circuit current without other countermeasure
- GTG and STG belonging to the same GCCT should be operated simultaneously:
  GTG and STG of same GCCT should be connected to the same bus for less 33 kV and 230 kV bus operation restriction or smooth operation of each GCCT
- The 33 kV bus current of Thilawa under normal operation should be kept at low level:
  Option 4 seems to be able to reduce the bus current the most compared with other cases
- The additional equipment cost [mostly step-up transformer] seems to be almost the same between Option 1 and Option 4 although Option 2 and Option 3 have high cost:
  Both Option 1 and Option 4 could utilize the existing step-up transformer.

However, this Option 4 had some problems as mentioned below from the viewpoints of close cooperation with EPGE and DPTSC.

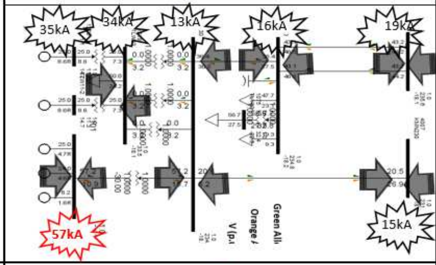
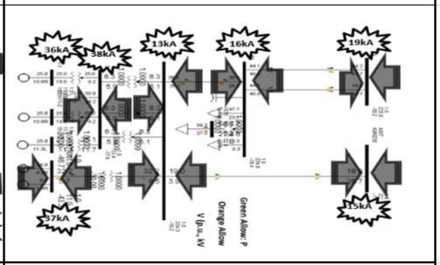
- It requires the operation of three transformers in parallel for meeting the increasing demand of Thilawa SEZ
- There is actual connection restriction of 33 kV GIS equipment including the space of Control Building in which related facilities are installed.

Therefore, further study was conducted for the additional connection cases as described hereafter:

b) Further Study for Additional Connection Cases of Generators in Thilawa Power Station

In addition to the options mentioned previously, the following cases which are connected to 230 kV bus directly through new 11/230 kV transformer were considered for avoiding the abovementioned problems in close cooperation with Myanmar's side as shown in Table 3.4.4-2.

Table 3.4.4-2 Additional Connection Cases of Generators in Thilawa Power Station

Case NO		Case 1	Case 2
Configulation		**Thilawa STG and YWANA GCCT is connected to 230kV Bus directry** 	**Thilawa GCCT is connected to 33kV Bus and YWANA GCCT is connected to 230kV Bus directry** 
Short Circuit Aspect	Evaluation (Max Current)	× (57kA at THILAWA 11kV Bus)	△ (37kA at THILAWA 11kV Bus)
	Countermeasure	・Attact Step-Up Tr to each Ge	----
Operation Aspect		○ (Need to adjust O&M between GCCT and two Bus's)	◎ (O&M for Both GCCT's are conducted independantly)
Equipment Aspect (Rough Cost)		○ (Addtion: 11/230kV Tr *1)	▲ (Addtion: 11/230kV Tr*1 - 11/33kV Tr *1)
Total Evaluation		×	▲

Source: Prepared by the JICA Study Team

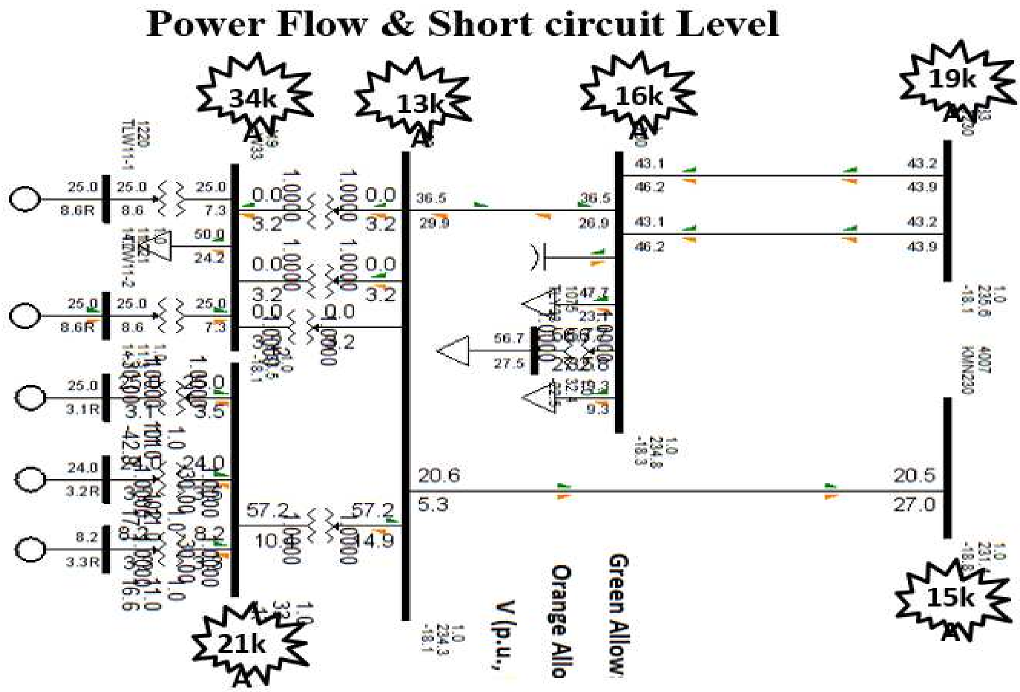
Judging from the further study mentioned above, the following points are concluded:

- It is possible to connect the output terminal of TG within two units from the short circuit capacity viewpoint.
- However, the connection of the output terminal of GT should be not recommended due to the effect of reduction of short circuit capacity.
- Connecting the output terminal of GT seems to be not preferable in terms of keeping smooth O&M such as separate operation of GT and ST and maintenance of common 11/230 kV transformer.
- There might be some safety risk for the maintenance of GTG or STG.

Finally, the following connection combination of TG in Thilawa Power Station was recommended:

c) Final Recommendation of TG Connection Method in Thilawa Power Station

Considering the study results and all aspects concerned, the TG Connection Method shown in Figure 3.4.4-19 in Thilawa Power Station was finally recommended under close cooperation with EPGE and DPTSC.



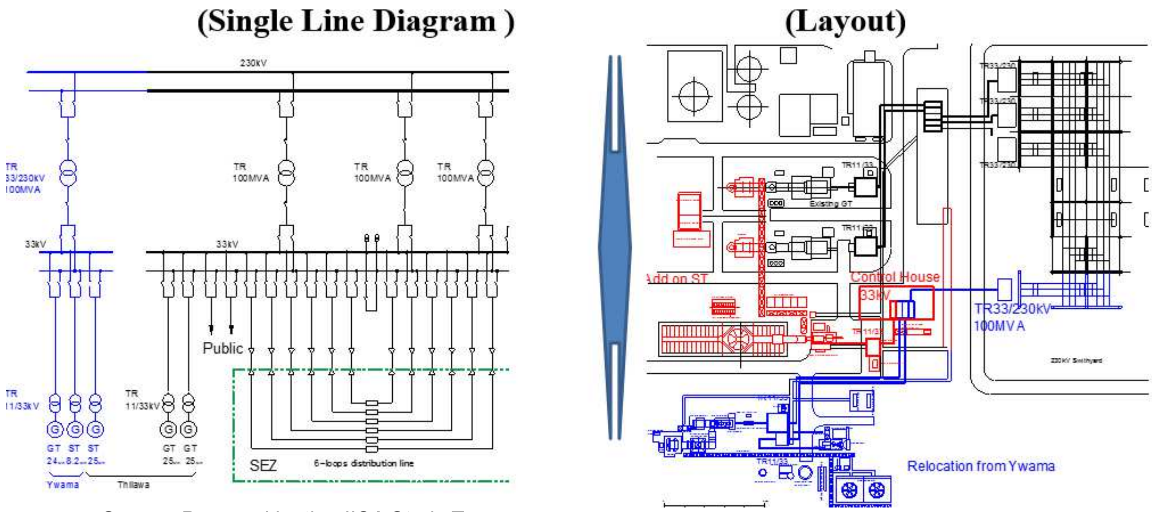
Source: Prepared by the JICA Study Team

Figure 3.4.4-19 Recommendation for TG Connection Method in Thilawa Power Station

The main characteristics of this connection method are as follows:

- The additional TGs should be connected to 230 kV bus through the step-up transformer respectively for reduction of short circuit level and keeping smooth O&M.
- The short circuit level of each related bus is reduced effectively.
- The existing three units of 33/230 kV transformer could be utilized to meet the increasing demand of Thilawa SEZ.
- There seems to be no problem regarding this configuration of TG connection from the power flow and short circuit level viewpoint and equipment spaces viewpoint as well.

The single line diagram and layout of this connection method are shown again in Figure 3.4.4-20 for reference.



Source: Prepared by the JICA Study Team

Figure 3.4.4-20 Single Line Diagram and Layout of Connection Method

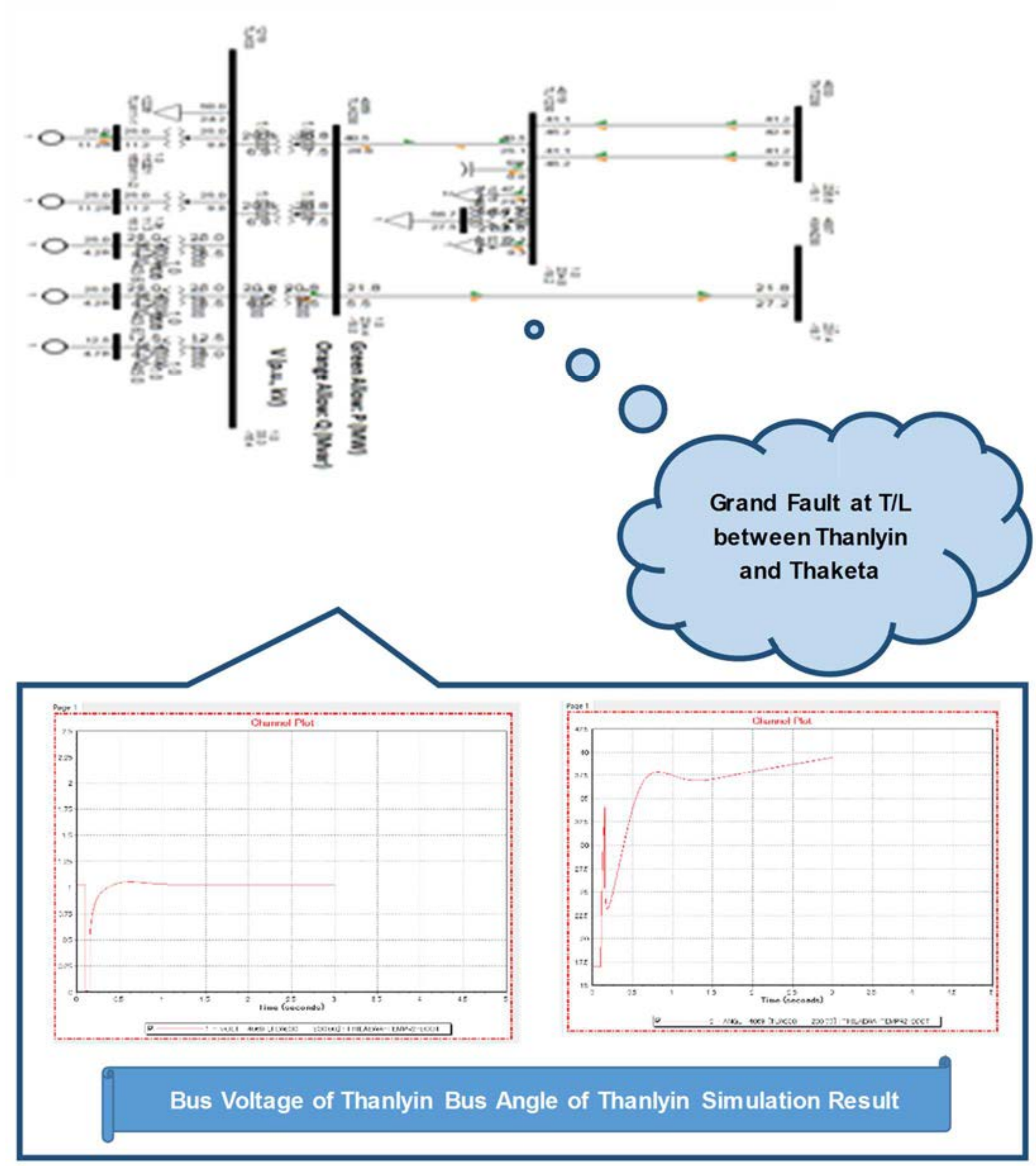
c) Evaluation of Transient Stability

Stability analysis of the 230 kV AC system in the local power system was tried to be carried out tentatively for the project. The location of the three-phase short circuit accident was selected in the 230 kV transmission line near a power plant under the severe condition and analysis was made by applying the accident condition of three-phase short circuit and clearing time of 50 ms tenably with shorten the actual fault relay clearing duration of 100ms for obtaining the generator angle performance curve.

The simulation result is shown in Figure 3.4.4-21 just for reference. Judging from the simulation result, it seems difficult to obtain the power swing of the TG machine itself as shown in Figure 3.4.4-22 depending on high speed and low inertia machine.

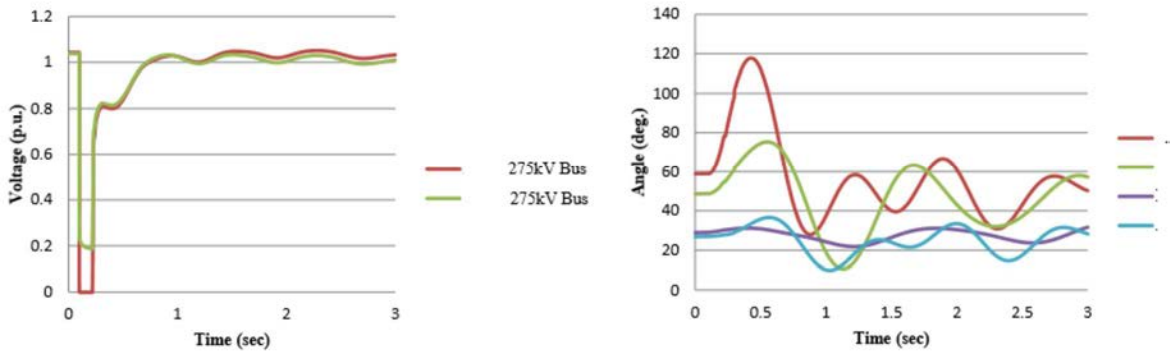
However, it seems stable after transmission accident in case of fault accident of 230kV transmission line near Thilawa P/S and the generators of Thilawa P/S might be tripped by protection relay itself such as under voltage or overcurrent beforehand.

Therefore, the following result is just for reference only:



Source: Prepared by the JICA Study Team

Figure 3.4.4-21 Simulation Result of Dynamics



Source: Prepared by the JICA Study Team

Figure 3.4.4-22 Example of Power Swing of Generators (Just for Reference)

3.4.5 Civil and Building Works

Since the Thilawa Add-on Project and the Ywama Relocation Project are carried out on the same premises, it is important to consider the existing situation regarding civil engineering construction and plan a cooperation between the two projects.

For civil engineering work, it should be planned to make efficient construction by fully utilizing the construction experience of existing simple cycle power generation equipment.

In addition, it is necessary to formulate a cooperative plan as two projects when using existing buildings and preparing newly constructed buildings.

The contents of the main civil engineering construction work are described below.

- Installation of equipment foundations and building foundation
- Foundation will be supported with RC piles
- Installation of electrical and control building
- Pile driving by hydraulic driving machine (vibration-free method)
- Extension of existing boundary wall (if necessary)
- Installation of cable and pipe trenches
- Installation of duct banks
- Installation of concrete paved surface for maintenance area
- Installation of gravel paved surface
- Other necessary civil building works as required

Chapter 4 Cost Estimation and Implementation Schedule of the Project

4.1 Project Cost Estimation

The JICA Study Team estimated the cost for the two projects, i.e., Thilawa Power Station Combined Cycle and Ywama Power Station Relocation Repair.

Based on the EPC cost data published as an estimation method, after correcting it according to the characteristics of each project, the JICA Study Team estimated the cost that is considered reasonable.

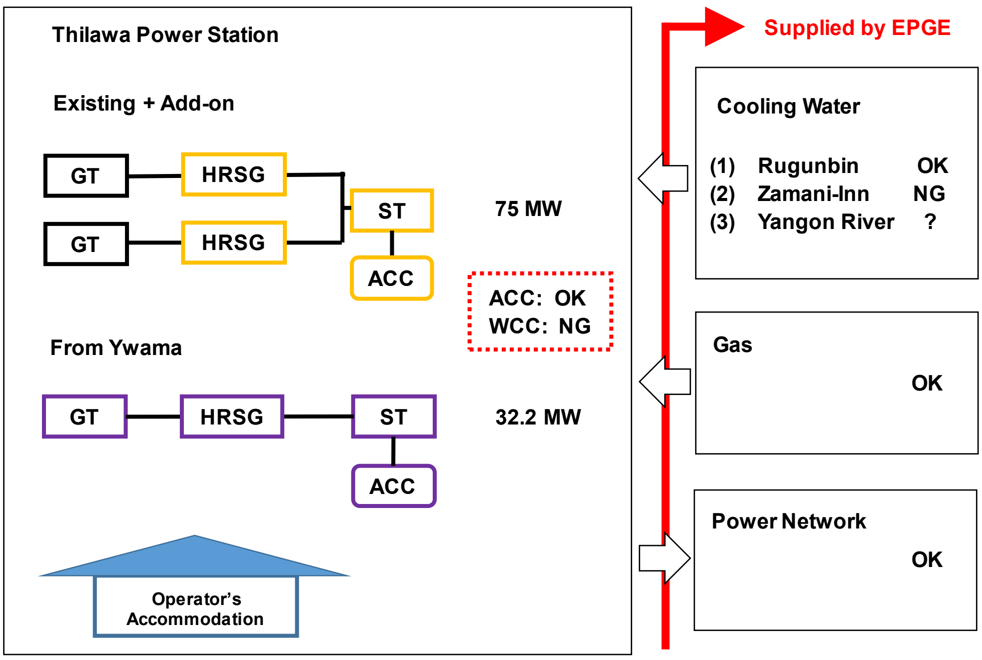
These procedures will be shown and explained below.

However, there are a few published EPC cost data in the world, and it will be useful if the JICA Study Team can find the contract price data of the concrete project as a reinforcement material of this trial calculation result.

In addition, as for the published EPC cost data, the conditions for each project naturally differ, so it can be considered that it is not appropriate to be adapted to the project unconditionally.

For example, the cost of acquisition of land, the development cost of land, the cost of withdrawing make-up water, the cost of withdrawing fuel gas piping, the maintenance cost of electricity grid, and the compensation cost to neighboring residents are not included in the EPC cost in general.

The image of the supply category of EPGE and EPC considered in this project is shown in **Figure 4.1-1**. It is necessary to clarify the supply range of EPGE.



Source: Prepared by the JICA Study Team

Figure 4.1-1 Input and Output for the Thilawa Power Station

1) Thilawa Add-on Cost Estimation

This section is not published at this public edition of the report.

2) Ywama Relocation Cost Estimation

This section is not published at this public edition of the report.

3) Actual cost data and analysis of the combined cycle power generation equipment

Up to this point, the JICA Study Team investigated the validity based on the data of the US Energy Information Administration (EIA) on add-on costs and relocation costs and calculated the cost considered appropriate. However, as a result, the JICA Study Team would like to know the construction cost in each country.

Therefore, the JICA Study Team gathered the actual cost from the information released by the press, homepage information of contractor and hearings.

Although there is a published order value, the JICA Study Team does not have detailed information such as scope of order receipt, so the JICA Study Team would like to take this as a reference value to grasp the image of cost.

In **Table 4.1-1**, as actual cost data, the information is described by the classification of add-on / combined cycle / simple cycle.

In the column on the right of the figure, the value of "$ / kW" is shown as kW unit price from the order receipt amount and the output of the power generation facility.

Furthermore, in the right column, "$ / kW" converted to the steam turbine output 25 MW is shown in the case of add-on. In the case of the combined cycle, "$ / kW" converted to a total output of 75 MW was shown.

Looking at these kW unit prices, there are considerable variations, but it is presumed to be due to differences in the scope of orders and different conditions at the site.

However, the JICA Study Team thought that it is possible to grasp a general trend from these converted values, and the cost examination mentioned above seems to be generally appropriate.

Table 4.1-1 Cost Analysis: Contract Actual Data of Power Generation Equipment

Cost analysis: Contract actual data of power generation (Add-on/Combined cycle/Simple Cycle)

* for Add-on Cost

Project Name	Location	Add-on Output (ST)	Total Output (C/C)	Contract Date	Completion Date	Type of Contract	Contract Amount	Customer / Country	Contractor	Delivery Date	Data Source	Remarks	Calculated kW Price			Convert to 25MW	
													MUSD	MW	$/kW	MUSD	$/kW
Takoradi T2 Expansion Project Add-on (1X120MW ST) Existing 110X2 + New 120 = 230MW	Republic of Ghana Western Region Shama District Aboadze	120MW	(340MW)	2012.7.12	2014.11	Full Turnkey	260 MUSD	TICO(Takoradi International Company) / Ghana	Mitsui & Co.	28.5 months	Mitsui & Co. Home page	KEPCO E&C as Consortium	260	120	2,167	91.4	3,655
Los Mina Power Plant Add-on (1X114MW ST) Existing 210 + New 114 = 324MW	Dominica Republic Santo Domingo Los Mina	114MW	(324MW)	2014.12	2016.12	Lamp Sum Full Turn Key	140 MUSD	DPP (Dominican Power Partners) / Dominican	Tecnicas Reunidas / Spain	27 months	Tecnicas Reunidas Home page		140	114	1,228	50.9	2,037

* for Combined Cycle Cost

Project Name	Location	Add-on Output (ST)	Total Output (C/C)	Contract Date	Completion Date	Type of Contract	Contract Amount	Customer / Country	Contractor	Delivery Date	Data Source	Remarks	Calculated kW Price			Convert to 75MW	
													MUSD	MW	$/kW	MUSD	$/kW
Northern Myanmar Mandalay (The country's largest gas-fired power plant)	Myanmar Mandalay Gas-fired power plant		220MW	?	2018	?	Investment Amount 300 MUSD	Singapore Government-based complex Semcorp Industries	GE U.S.A.	?	Press release	International Finance Corporation (IFC) supported	300	220	1,364	146.4	1,947
Muara Karang Combined Cycle Power Plant (Phase-II) 185MW x 1	Indonesia		185MW	1992	1995		247 MUSD	PLN	Sumitomo Corporation	3 years ?	Information from the contractor		247	185	1,335	135.3	1,804
Sylhet 90MW Combined Cycle Power Plant	Bangladesh		90MW	1993	1995		106 MUSD	BPDB	Sumitomo Corporation	2 years ?	Information from the contractor		106	90	1,178	93.9	1,252
Tambak Lorok Combined Cycle Power Plant Block-1 Phase – II 188MW x 1	Indonesia		188MW	1995	1997		228 MUSD	PLN	Sumitomo Corporation	2 years ?	Information from the contractor		228	188	1,213	123.6	1,648
Maputo Gas Fired Combined Cycle Power Plant Development Project (1×110MW)	Mozambique		110MW	2016	U.C.		149 MUSD	Electricidade de Mozambique	Sumitomo Corporation	?	Information from the contractor		149	110	1,355	115.4	1,539
Kinyerezi Natural Gas Fired Combined Cycle Power Plant Project (240MW)	Tanzania		240MW	2016	U.C.		345 MUSD	Tanzania Electric Supply Company Limited (TANESCO)	Sumitomo Corporation	?	Information from the contractor		345	240	1,438	158.9	2,119
Chana Combined Cycle Power Plant Block 2	South of Thailand Songkhla County Chana District		782MW (1-1-1×2)	-2011	-2014.8	Full Turnkey	(43.5 BJPY) 479 MUSD	Electricity Generating Authority of Thailand (EGAT)	Marubeni & Siemens	3 years ?	Marubeni Home page 2011.6.20	Joint order with Siemens Group The order value for (Marubeni is 18 billion yen)	479	782	613	105.3	1,404
Wang Noi Combined Cycle Power Plant Block 4	North Thailand Ayutaya Department Wan Noi District		769MW (2-2-1×1)	-2011	-2014.4	Full Turnkey	(39.5 BJPY) 435 MUSD	Electricity Generating Authority of Thailand (EGAT)	Marubeni & Siemens	3 years ?	Marubeni Home page 2011.6.20	Joint order with Siemens Group The order value for (Marubeni is 20 billion yen)	435	769	566	92.2	1,229
IRPC Cogeneration Project	Thailand Rayong		220MW 6GT + 6HREG	2009.9	2011.5		124 MUSD	IRPC Public Company Limited	Marubeni	2 years ?	Marubeni Home page 2009.9.14	Excluding GTG and civil engineering	124	220	564	60.5	807
Bibiyana-III Gas Based Combined Cycle Power Plant	Bangladesh Bibiyana		400MW	-2016	2018		(30.8 BJPY) 339 MUSD	Bangladesh Power Development Board (BPDB)	Marubeni	2 years ?	Marubeni Home page 2016.3.1	Marubeni & BPDB	339	400	848	111.1	1,481
South Bangkok Power Plant Replacement Project Phase 1	Thailand Bangkok		1200MW (1-1-1×2)	-2016	-2019	Full Turnkey	(60.0 BJPY) 660 MUSD	Electricity Generating Authority of Thailand (EGAT)	Marubeni & Siemens	3 years ?	Marubeni Home page 2017.1.25	Marubeni's charge BOP, civil engineering, installation etc.	600	1200	500	94.5	1,260

* for Simple Cycle Cost

Project Name	Location	Add-on Output (ST)	Total Output (C/C)	Contract Date	Completion Date	Type of Contract	Contract Amount	Customer / Country	Contractor	Delivery Date	Data Source	Remarks	Calculated kW Price			Convert to 50MW	
													MUSD	MW	$/kW	MUSD	$/kW
Nigeria NIPP Simple Cycle Thermal Power Plant	Nigeria - Cross River State - Edo State - Delta State	1,463MW			2015		382 MUSD Transport & Construction	Niger Delta Power Holding Company	Marubeni	NA	Marubeni Home page	- 563MW - 450MW - 450MW	NA	NA	NA	NA	NA

Source: Official Data and Hearing by the JICA Study Team

4.2 Implementation Schedule

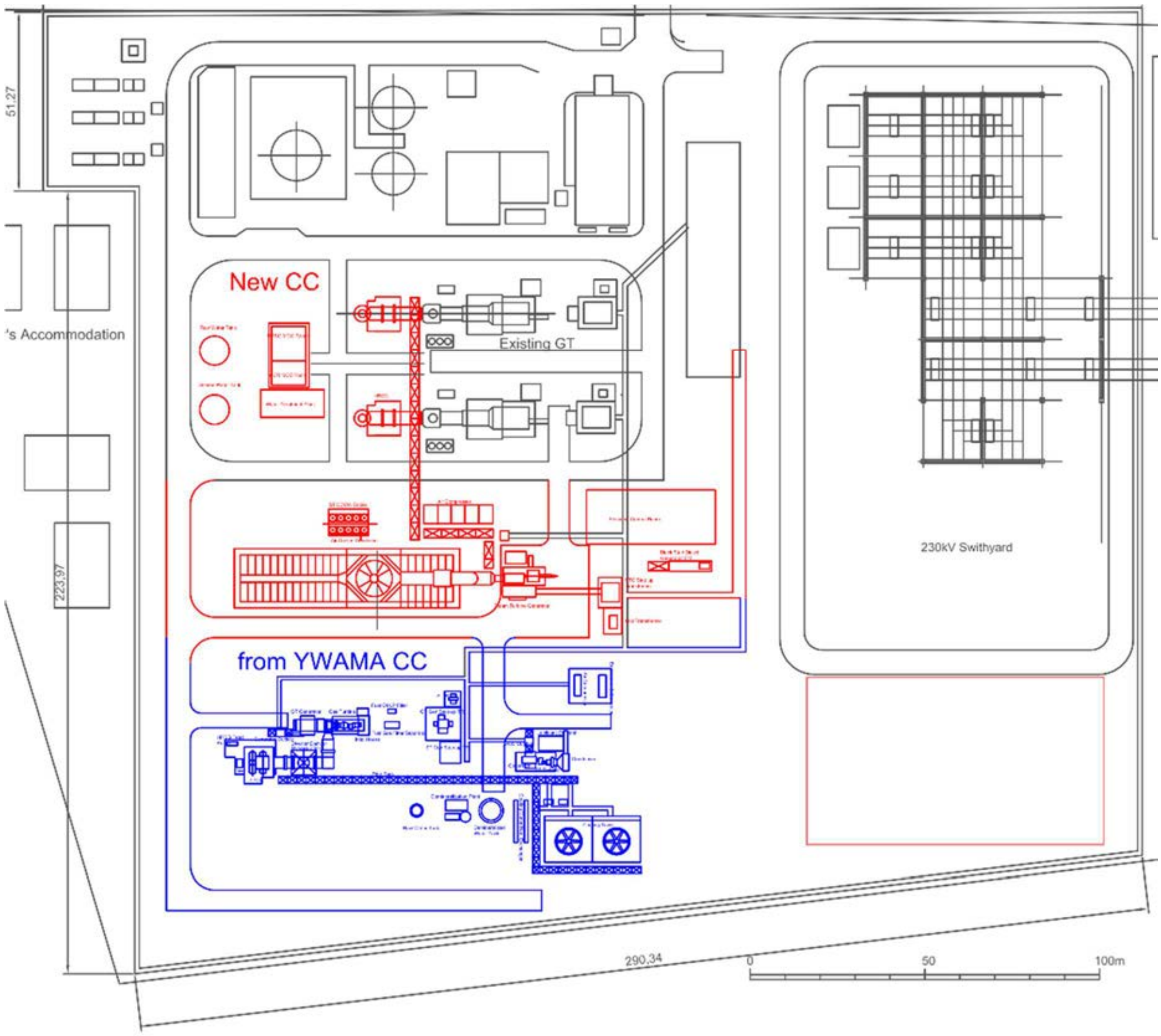
It is highly likely that this project will be divided into two projects, i.e.: Thilawa Add-on and Ywama Relocation.

This is the result of the examination done in Chapter 3, and it is possible to reduce the overall risk by separating the projects with uncertain elements such as relocation and renovation and add-on projects that can be proceeded easily with planning.

This method was selected as a result of consideration of Option 4. (For the technical content of Option 4, see Chapter 3)

Although it is a repetitive description, the execution place of these two projects is within the Thilawa Power Plant in **Figure 4.2-1**, the red part in the figure is the add-on area, and the blue part in the figure is the relocation area.

In addition, residence for staff of power stations will be required at the same time as this project is implemented. Priority is given to the arrangement of the power generation facilities and the residence will be planned at the appropriate position.

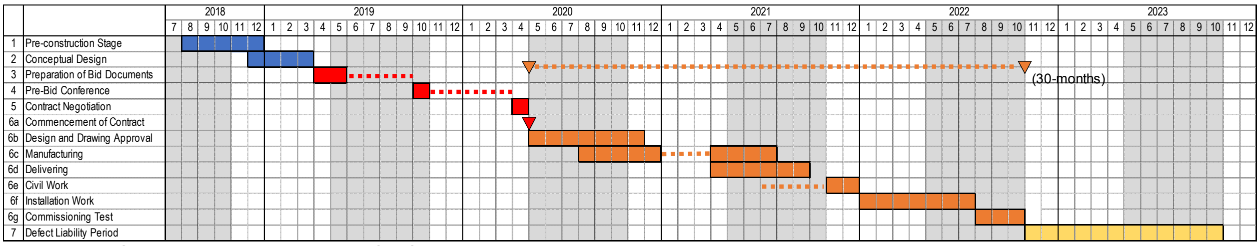


Source: Prepared by the JICA Study Team

Figure 4.2-1 Layout of the Thilawa Power Station

Thilawa Add-on Implementation Schedule

The implementation schedule of Thilawa Add-on is 30 months as shown in **Figure 4.2-2**.



Source: Prepared by the JICA Study Team

Figure 4.2-2 Implementation Schedule of Thilawa Add-on

For the quality control of construction work, especially concrete placement under the foundation construction of power generation facilities, the JICA Study Team would like to avoid the rainy season in Myanmar if possible.

For this reason, the JICA Study Team anticipated a margin later in the rainy season to leave the foundation work.

Also, at present, the delivery date of the turbine rotor cannot be grasped precisely until the actual order is made.

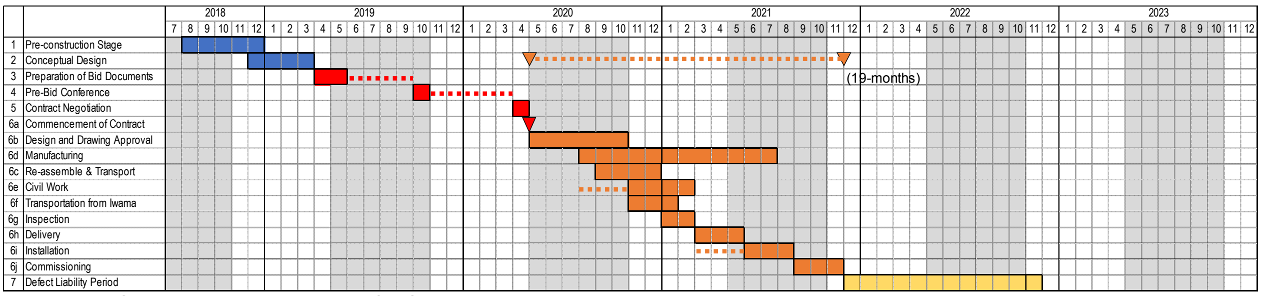
Manufacturing risk of equipment that becomes critical in such process is expected in the construction term of 30 months.

As for the shortening of the construction period, it is good to exchange ideas between the ordering party and the contractor, and then negotiate the deadlines of equipment critical at that point and decide the method.

Similarly, from the viewpoint of shortening the later stage, it is better to decide how to avoid the rainy season in Myanmar from the start of construction of the foundation by the contractor side.

Ywama Relocation Implementation Schedule

The implementation schedule of Ywama Relocation is 19 months as shown in **Figure 4.2-3**.



Source: Prepared by the JICA Study Team

Figure 4.2-3 Implementation Schedule of the Ywama Relocation

Although there is a plan to carry out release check of gas turbine and other major equipment at Ywama Power Plant before the construction starts, in particular if it is focused on rotating equipment such as gas turbine and steam turbine, rather than doing an open inspection, it is recommended to have a plan to relocate the Thilawa Power Station first and then open inspection.

This is because it is thought that it is more advantageous for delicate adjustments such as alignment adjustment if the rotating machine is installed as it is on the new foundation.

In any case, since the JICA Study Team will divide it into two projects this time, sharing information between the team contractors and each contractor and collaborating with each other will lead to good results.

In Thilawa Special Economic Zone (SEZ), two units of gas turbine power generation (GTG) plant with a rated capacity of 25 MW each have been installed through a JICA loan and the power plant supplies to Thilawa SEZ and Yangon. The power demand at Thilawa SEZ, however, will exceed the power supply (50 MW) of the power plant in the future. Considering this forecast, the reinforcement of power supply is an urgent matter for Thilawa SEZ. Furthermore, the generated power from the power plant will be supplied to the national grid towards Yangon considering the low load at the Thilawa SEZ during night time. Thus, the development plan in accordance to reinforcement of national grid/distribution line in/nearby Yangon should also be studied.

In consideration to the above situation, JICA will conduct a study on the current power supply situation in/near Thilawa and Yangon, and submit a proposal to the Government of Myanmar. The alternatives (four options) for upgrading the power supply system in Thilawa area will be proposed from the aspects of electrical and thermal techniques with economic and financial considerations. In this chapter, the requirements of environmental and social considerations on the proposed options will be discussed.

Chapter 5 Environmental and Social Consideration

5.1 Environmental and Social Laws and Regulations in Myanmar

5.1.1 Laws and Regulations on Environmental and Social Considerations

1) National Policy/Plan

Currently, in Myanmar, the department responsible for the environment and social managements is the Environmental Conservation Department (ECD) under the Ministry of Natural Resources and Environmental Conservation (MONREC). The corresponding regional or state government is also involved in the environmental and social considerations. For this proposed project, the Ministry of Electricity and Energy, the project owner, and the project proponent take the main responsibility in the environmental and social consideration of this project.

The major legislations pertinent to natural environment and social environment areas in Myanmar totaled to about 86 laws/rules/regulations and also, regarding the environmental conservation aspects, about seven policies/laws/procedures/guidelines are under drafting process with the support of international organizations (JICA, ADB, WB, etc.). The important procedure and guidelines named as Environmental Impact Assessment Procedures and as National Environmental Quality (Emission) Guidelines (NEQG), respectively, are stipulated in December 2015. New projects or expansion projects are applied to the procedures and the guidelines in the above.

2) Environmental Standards

The following **Table 5.1.1-1** shows the guidelines values for the Gas Turbine Project and its related project described in the NEQGs. The environmental standards for the proposed project should comply with the NEQGs.

Table 5.1.1-1 Outline of the National Environmental Quality (Emission) Guidelines (Gas Turbine Project and its Related Project)

Environment Element	Guideline Value	Note
Emission gas	NO_x:100 mg/Nm^3	For gas turbine project (not less than 50 MW)
Wastewater	As: 0.5 mg/L, Cd: 0.1 mg/L, Total Cr: 0.5 mg/L, Cu: 0.5 mg/L, Fe: 1 mg/L, Pb: 0.5 mg/L, Hg: 0.005 mg/L, Oil & Grease: 10 mg/L, pH : 6-9, Temperature Increase: less than 3°C, Total residual chlorine: less than 0.2 mg/l, Total suspended solids: 50 mg/L, Zn: 1mg/L	For thermal plant
Noise	**Residential, institutional, educational** [Weekday] 55 dB (7:00 a.m. to 10:00 p.m.), 45 dB (10:00 p.m. to 7:00 a.m.) [Weekend] 55 dB (10:00 a.m. to 10:00 p.m.), 45 dB (10:00 p.m. to 10:00 a.m.) **Industrial, commercial** 70 dB (all day)	Guideline values are applied to all sectors but criteria for the left land use is not clear

Source: Myanmar National Environmental Quality (Emission) Guideline（2015）

(i) Requirement of IEE or EIA for project implementation

Table 5.1.1-2 summarizes the requirements of IEE or EIA study in accordance with the EIA procedures.

Table 5.1.1-2 Projects Required to Implement the EIA or IEE Study under the EIA Procedures (Gas Turbine Project and its related Project)

Type of Economic Activity	IEE (Initial Environmental Examinations)	EIA (Environmental Impact Assessment)
Natural Gas Power Plants	Installed capacity ≥ 5 MW but < 50 MW	Installed capacity ≥ 50 MW
Combined Cycle Power Plants (gas and thermal)	Installed capacity ≥ 5 MW but < 50 MW	Installed capacity ≥ 50 MW
Gas Transmission or Distribution Systems	< 10 km	≥ 10 km
Electrical Power Transmission Lines ≥ 115 kV but < 230 kV	≥ 50 km	All activities where the ministry requires that the Project shall undergo EIA
Electrical Power Transmission Lines ≥ 230 kV	All	Ditto
High Voltage (230 kV and 500 kV) Transformer Substations	≥ 4 ha	Ditto

Source: Annex-1 of EIA Procedures (2015)

As per Annex-1 of EIA procedures, the EIA study will be required in case of an expansion of Thilawa Power Plant. However, the draft EIA report has been prepared for the existing power plant (50 MW). Hence, as a result of the discussion of the JICA Study Team with the MONREC-ECD in August 2017, the updating of the existing draft EIA report for 50 MW will be required. Also, the ECD suggested to apply the review of the updated EIA report for the expansion/upgrading of Thilawa Power Plant Project. However, the revision of the existing draft EIA report shall comply with the EIA procedures and NEQGs.

(ii) Approval process of EIA for implementation of the proposed project

The expected timeframe of the updating of EIA study for the upgrading project is shown in **Table 5.1.1-3**. It may take a total of about 12.5 months from the preparation for updating the draft EIA report to obtain the approval of the EIA report issued by the MONREC after the appraisal of the National Environmental Conservation and Climate Change Central Committee (NECCCCC). It can be noted that the approval of the EIA report is presently issued by MONREC prior to the issuance of the Environmental Compliance Certificate (ECC), which is the certificate needed for the EIA study proposed in the EIA procedures.

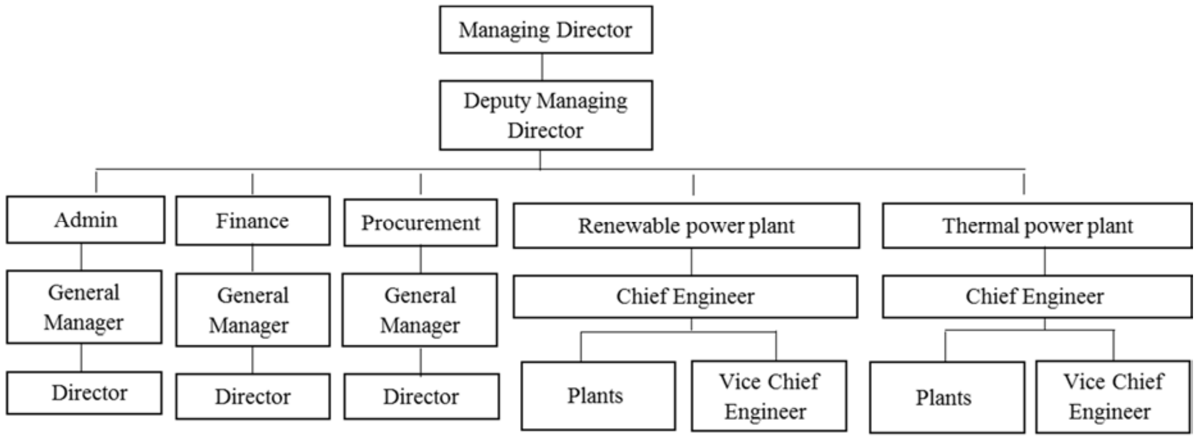
Table 5.1.1-3 Expected Schedule of EIA Study for the Proposed Project

No.	Description of Actions	Expected / Required Time Period	Remark
0	Completion of F/S Report		
1	Preparation for updating the draft of the EIA Report	2 months	
2	Arranging public consultation, disclosure and finalization of EIA Report	2 months	
3	Submission of final EIA Report* and Appraisal	4.5 months	*MOEE's cover letter on request of urgent review shall be required.
4	Approval by NECCCCC*	4 months	* National Environmental Conservation and Climate Change Central Committee * Committee meeting is organized every 4 months

Source: Prepared by the JICA Study Team

(iii) Organizations/institutions responsible for the implementation of environmental and social considerations for the proposed project

The Electric Power Generation Enterprise (EPGE) under the Ministry of Electricity and Energy (MOEE) is the responsible organization to implement the environmental and social management plans for upgrading the project. The organizational structure of EPGE is described in **Figure 5.1.1-1**.



Source: EPGE

Figure 5.1.1-1 Organizational Structure of EPGE

5.2 Environmental and Social Baseline Conditions near the Project

5.2.1 Overall Environmental and Social Conditions in the Surrounding Area

The overall environmental and social conditions in Thanlyin and Kyauktan township areas are described in this section.

1) Natural Environment

(i) Meteorology

There are three seasons defined in Greater Yangon having tropical monsoon climate characteristics: the summer season starts from March to May, the rainy season starts from June to October and the winter starts from November to February. The Kaba-aye Meteorological Station, which is managed by the Department of Meteorology and Hydrology (DMH) under the Ministry of Transport and Communications (MOTC), has been observing the meteorological conditions of Greater Yangon including the Thilawa area since 1968.

(ii) Temperature and Rainfall

From 2006 to 2015 the mean annual temperature is 27.43 °C. The mean monthly temperature is highest in April at 30.6 °C and lowest in January at 24.9 °C. Except in January, the monthly mean temperature is above 25.0 °C. The southwest monsoon wind is the main source of rain, and the Yangon area receives rain during the period from May to October. The average annual amount of rainfall is 245.42 mm. Rainfall sharply decreases from November and continues to be less than 16 mm from December to February. According to Koppen's Climate Classification, the type of climate is tropical monsoon (am), which is characterized by alternating wet and dry seasons. The average relative humidity in Yangon is 78% during 2006-2015.

The mean monthly temperature is highest in April at 30.7 °C and lowest in January at 25.0 °C. Except in December and January, the monthly temperatures are above 25.0 °C. The southwest monsoon wind is the main source of rain, and the Yangon area receives rain during the period from May to October. The average annual amount of rainfall is 2,787 mm. Rainfall sharply decreases from November and continues to be less than 10 mm from December to February, as shown in **Table 5.2.1-1**.

Table 5.2.1-1 Monthly Maximum, Minimum, Mean Temperatures, and Rainfall at Kaba-aye Station in Yangon City (2006-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average / Total
Max. Temp. (°C)	32.2	34.5	36.0	37.0	33.4	30.2	29.7	29.6	30.4	31.5	32.0	31.5	32.33
Min. Temp. (°C)	17.9	19.3	21.6	24.3	25.0	24.5	24.1	24.1	24.2	24.2	22.4	19.0	22.55
Mean Temp. (°C)	24.9	26.8	29.0	30.6	28.9	27.4	26.8	26.8	27.1	27.9	27.6	25.4	27.43
Rainfall (mm)	6	1	17	42	378	533	673	541	455	240	53	6	245.42

Source: Data of the Department of Meteorology and Hydrology, Kaba-aye Station, Yangon in the Statistical Year Book (2016)

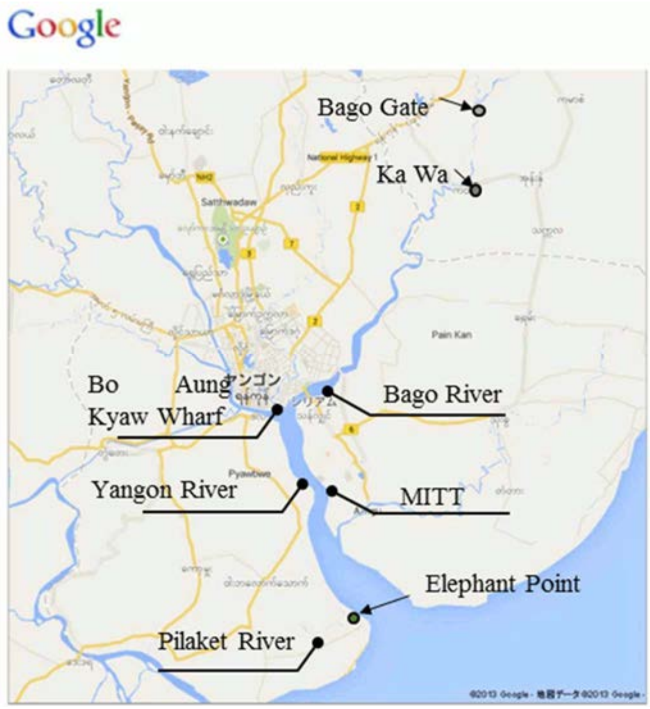
(iii) Hydrological Situation

The main river around Thilawa SEZ is the Yangon River, which is a large tidal river in the region running on the west side of Thilawa SEZ. The data on the tide levels of the Yangon River as observed from the elephant point is shown in the following **Figure 5.2.1-1** and by the Ministry of Port Authority (MPA) as shown in **Table 5.2.1-2**. The elephant point is located at the mouth of the Yangon River, 32 km south from the Yangon Port. The data of the MPA are converted in accordance with Myanmar's standard sea level.

Table 5.2.1-2 Hydrological Data on the Yangon River

Description	Data of Sounding at Elephant Point (m)
Highest HWL (September 1930)	+4.390
MWL in Bo Aung Kyaw Wharf	+0.856
MWL in Pilaket Creek	+0.591
Zero of Tide Gauge in Yangon	-2.265
Lowest LWL (February 1888)	-2.265
High Tide Duration	1.2 hr

Source: JICA Preparatory Study on Thilawa SEZ Infrastructure Development in the Republic of the Union of Myanmar (March 2014)



Source: JICA Preparatory Study on Thilawa SEZ Infrastructure Development in the Republic of the Union of Myanmar (March 2014)

Figure 5.2.1-1 Location of Rivers and the Elephant Point

Source: Preparatory Study on Thilawa SEZ Infrastructure Development in the Republic of the Union of Myanmar (2014)

Figure 5.2.1-2 Surface Water in and around Thilawa SEZ

In Thilawa SEZ, there are six tidal rivers and small stream as seen above in **Figure 5.2.1-2**. Four of them, namely: Ah Lun Sake Creek, Shwe Pyauk Creek, Pa Lan Creek, and a small creek flowing into the Yangon River. In the south area of Thilawa SEZ, Gway Creek, and Kayat Creek flow into the Hmawwun River, which flows from east to west and reaches the Yangon River.

In and around the Thilawa SEZ, there are three major water reservoirs, namely: Zarmani Reservoir, Bant Bwaykone Reservoir, and Thilawa Reservoir.

(iv) Flora, Fauna, and Biodiversity

According to the results of the Flora and Fauna Survey in 2013, there were 139 flora species in the dry season and 181 species in the rainy season in the Thilawa SEZ Zone A area and the downstream near the Yangon River. The listed and recorded plant species were checked with the International Union for Conservation of Nature (IUCN) Red List of threatened species. However, none of those species were found in the IUCN Red List.

The fauna survey was also conducted in 2013 in and around the Thilawa SEZ Zone A. A total of 13 butterfly species were recorded in the study area during the survey period. All the recorded butterfly species were common species. A total of 18 bird species, which belong to 13 families, were recorded in the survey area. A total of four mammal species categorized as Least Concern (LC) by IUCN Red List were recorded during the survey period. Some species such as the white-bellied rat (*Niviventer fulvscens*) and the greater bandicoot rat (*Bandicota Indica*), were found mainly in the rice fields, whereas the grey squirrel (*Callosciurus Pygerythrus*) was found in the scattered trees and scrubland areas.

A total of 18 reptilian species and seven amphibian species were recorded in the survey area during the survey period and the total 18 species in the dry season and eight species in the rainy season had the LC status in the IUCN Red List. The reptile species, *Calotes versicolor*, was observed in areas with mixed vegetation and scattered trees. Among the recorded species, the paddy frog, *Fejervarya limnocharis*, was found as a very common species. The frog species, *Holobatrachus tigerinus* was also common in the area and distributed in many parts of the area in the wet season. A total of 15 fish species were recorded during the survey period. The fishes are important for the ecosystem of the canal and rice field water body. The fish species, *Mystus cavasius* and *Puntius chola*, were found as the most common species in the Thilawa SEZ Zone A. The fish species, *Mystus bleekeri* and *Labeo calbasu*, were also abundant in the aquatic habitat. As a result of the survey, endangered (EN) species, vulnerable (VU) species by IUCN Red List, and prohibited species, which need to be conserved by implementing a no hunting, trading, and no disturbance by the Myanmar Law, were not identified by the Flora and Fauna Survey in 2013.

(v) Protected/Reserved Area

There is no protected area including natural reserve, national park, wildlife sanctuary and bird sanctuary around Thilawa SEZ.

(vi) Land Use

In Thanlyin and Kyauktan townships, lands are mainly used for agriculture purpose with 74.5% and water with 14.3%, as of 2012/2013 (As of JICA/Sanyu Consultants Inc., Data Collection Survey on Water Resources Potential for Thilawa SEZ and Adjoining Areas Final Report, September 2014). Special Economic Zone (Industrial Use) occupied 1.43% (500 ha) of Thanlyin townships, as of 2017.

2) Social Environment

(i) Population

Thanlyin Township is located in the southern part of Yangon Region and its eastern and northern parts are facing the Bago River and the Yangon River. Then, the western and southern parts are adjoining the Thongwa Township, Kayan Township, and Kyauktan Township, respectively. Thanlyin Township is made up of 17 wards, 29 village tracts and village tracts are composed of 57 villages. The number of household in Thanlyin Township is 61,597 according to the 2014 Census.

Kyauktan Township is located in the southern part of the Yangon Region and its eastern parts and northern parts are adjoining the Thongwa Township and Thanlyin Townshp. And then, the western and southern parts are adjoining the Yangon River and Mottema Ocean. Kyauktan Township is made up of 9 wards, 32 village tracts. The number of household in Kyauktan Township is 32,976 according to the 2014 Census.

(ii) Water Usage

The sources of drinking water and non-drinking water in Thanlyin and Kyauktan townships are shown in **Table 5.2.1-3** and **Table 5.2.1-4**, respectively. More than 60% of the households in Thanlyin Township are using water for drinking and non-drinking purposes from wells, while about 70% of households are using water from the pool/pond/lake in Kyauktan Township. On the other hand, as shown in **Figure 5.2.1-3**, most of the wells in Thanlyin Township are located outside of the Thilawa SEZ.

Table 5.2.1-3 Source of Drinking Water in Thanlyin and Kyauktan Townships

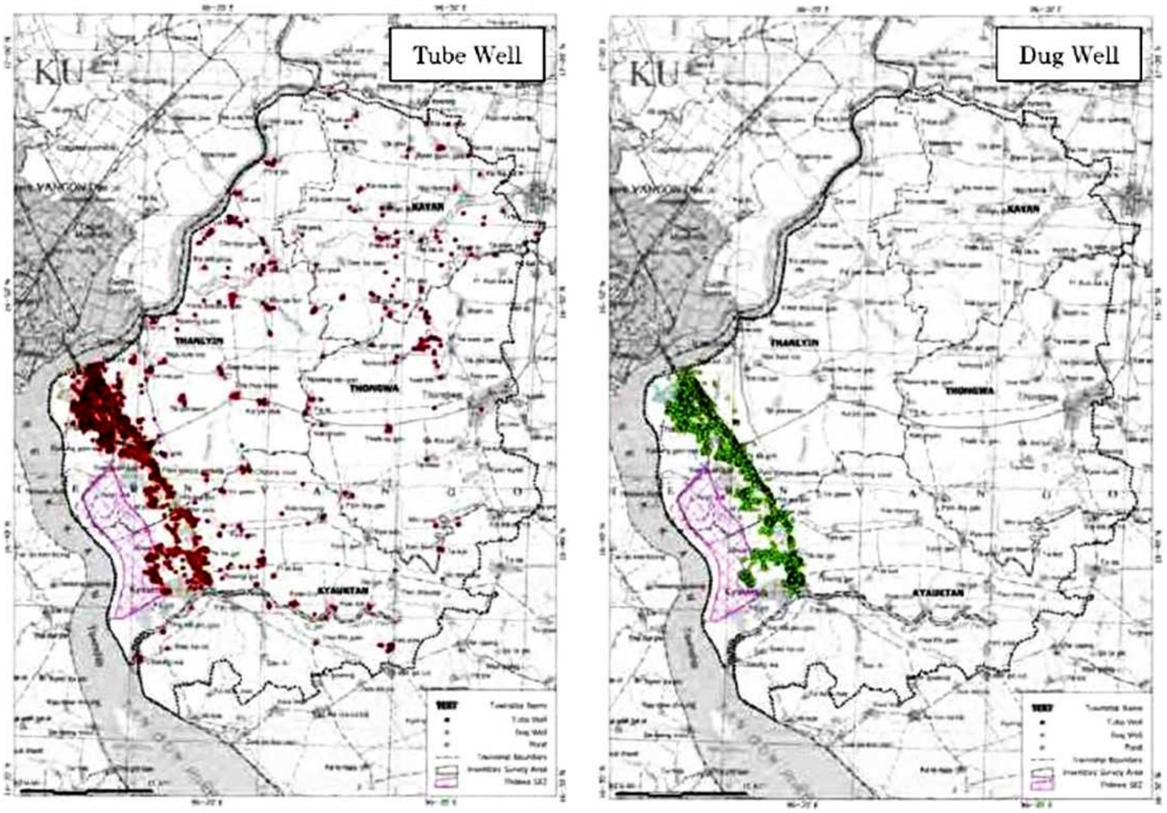
Township	Source of Water	Tap Water/ Piped	Tube Well, Borehole	Protected Well / Spring	Unprotected Well/Spring	Pool / Pond / Lake	River / Stream	Waterfall / Rainwater	Bottled Water Purifier	Tanker / Truck	Other	Total
Thanlyin	Number	1,392	24,925	10,389	3,602	14,190	33	185	5,595	91	1,195	**61,597**
	(%)	2.3	40.5	16.9	5.8	23	0.1	0.3	9.1	0.1	1.9	**100**
Kyauktan	Number	1,804	2,171	3,961	1,092	22,833	14	103	864	5	129	**32,976**
	(%)	5.5	6.6	12	3.3	69.2	0.04	0.3	2.6	0.02	0.4	**100**

Source: Department of Population, Ministry of Immigration and Population "The 2014 Myanmar Population and Housing Census–The Union Report- Census Report Volume 2" May 2015

Table 5.2.1-4 Source of Non-drinking Water in Thanlyin and Kyauktan Townships

Township	Source of Water	Tap Water/ Piped	Tube Well, Borehole	Protected Well / Spring	Unprotected Well/Spring	Pool/Pond/ Lake	River / Stream / Canal	Waterfall / Rainwater	Bottled Water / Water Purifier	Tanker / Truck	Other	Total
Thanlyin	Number	3,062	29,188	9,770	3,618	14,545	60	5	63	19	1,267	**61,597**
	(%)	5	47.4	15.9	5.9	23.6	0.1	0.01	0.1	0.03	2.1	**100**
Kyauktan	Number	2,292	3,376	3,183	995	22,935	15	3	34	2	141	**32,976**
	(%)	7	10.2	9.7	3	69.6	0.05	0.01	0.1	0.01	0.4	**100**

Source: Department of Population, Ministry of Immigration and Population "The 2014 Myanmar Population and Housing Census–The Union Report- Census Report Volume 2" May 2015



Source: JICA/Sanyu Consultants Inc., Data Collection Survey on Water Resources Potential for Thilawa Special Economic Zone and Adjoining Areas Final Report, September 2014

Figure 5.2.1-3 Distribution of Tube and Dug Wells in Thanlyin and Kyauktan Townships

3) Social-Economic Condition

The main sources of livelihood in the two townships are agriculture, fishing, and official employment in the government as shown in **Table 5.2.1-5**. In Thanlyin Township, other sources of earning are livestock breeding, fish farming, casual labor, and betel leaf and coconut plantations as well as small- to medium-sized businesses. In Kyauktan Township, other livelihood activities include livestock breeding, fish farming, and betel leaf and coconut plantations. Most of the casual laborers are employed in the agricultural sector. According to the survey results of Resettlement Framework for 2,000 ha, it is confirmed that more or less 10 households are engaged in the aquaculture in and around Thilawa SEZ, and the fishponds are mainly located along Alunsut Creek. In addition, about 20 households are cultivating not only monsoon paddy fields but also summer paddy fields by utilizing the irrigated water from the existing water source including creeks which flow in and around Thilawa SEZ.

Table 5.2.1-5 Existing Status of Local Livelihoods in Thanlyin and Kyauktan Townships (2014)

Township	Type of Workers (Person)							
	Govt. Staff	Service Staff	Agriculture	Livestock	Trader	Factory	Odd Job	Others
Thanlyin	7,436 (6.9%)	2,675 (2.5%)	6,650 (6.2%)	175 (0.2%)	21,003 (19.5%)	6,230 (5.8%)	41,972 (39.0%)	21,623 (20.1%)
Kyauktan	4,305 (5.2%)	11,000 (13.3%)	4,307 (5.2%)	8,706 (10.5%)	6,637 (8.0%)	5,378 (6.5%)	6,569 (7.9%)	35,851 (43.3%)

Source: Thanlyin and Kyauktan Township Administrative Offices

5.2.2 Baseline Environmental Conditions of the Upgrading Project

The overall conditions of air quality, water quality and noise levels at the surrounding areas of the proposed project site are quoted from the existing data such as the monitoring report for the Thilawa Power Plant in which noise and vibration levels were measured in July 2016 and the monitoring report for Thilawa Substation in which air quality, water quality and noise and vibration were measured in May 2017; and water quality was measured in July 2017. The location of the environmental survey for overall conditions is shown in **Figure 5.2.2-1, Figure 5.2.2-2** and **Figure 5.2.2-3**

Source: Environmental monitoring report for Thilawa Power Plant (July 2016)

Figure 5.2.2-1 Location Map of Noise and Vibration Monitoring Point for Thilawa Power Plant in July 2016

Source: Environmental Monitoring Report for Thilawa Substation (May 2017)

Figure 5.2.2-2 Location Map of Air Quality, Noise, Vibration and Water Quality Sampling Points for the Thilawa Substation in May 2017

Source: Environmental Monitoring report for Thilawa Substation (July 2017)

Figure 5.2.2-3 Location Map of Water Quality Sampling Points for the Thilawa Substation in July 2017

1) Air Quality

According to the Myanmar National Environmental Quality (Emission) Guidelines (December 2015), NO_2 (24 hours) and SO_2 (10 minutes) levels are lower than the standard. The PM10, PM2.5 and SO_2 (24 hours) levels are slightly higher than the standard. The increase in PM and SO_2 values may be results from the construction work of transmission lines project on Dagon-Thilawa Road as shown in **Table 5.2.2-1**.

Table 5.2.2-1 Ambient Air Quality

Date and Duration	Parameter	Result (Average) (μg/m³)	(NEQG Standard) (μg/m³)	Remark
4-5-2017, 2:00 - 3:00 PM	Nitrogen Dioxide (for 1 hour)	3.76	200	OK
4-5-2017, 1:00 PM 5-5-2017, 1:00 PM	Particulate Matter (PM_{10}) (for 24 hour)	56.47	50	Slightly Higher
4-5-2017, 1:00 PM 5-5-2017, 1:00 PM	Particulate Matter ($PM_{2.5}$) (for 24 hour)	51.94	25	Higher
4-5-2017, 1:00 PM 5-5-2017, 1:00 PM	Sulfur Dioxide (for 24 hour)	33.86	20	Higher
4-5-2017, 2:00 - 2:10 PM	Sulfur Dioxide (for 10 minute)	30.1	500	OK

Source: Environmental Monitoring Report for the Thilawa Substation (May 2017)

2) Water Quality

According to the Myanmar National Environmental Quality (Emission) Guidelines (December 2015), pH, oil and grease and total phosphorous levels are lower than the standard. SS, BOD, COD and T-coli levels are higher than the standard. The water quality in the surrounding areas of Thilawa Substation Project failed to meet the NEQG values as shown in the **Table 5.2.2-2**. Hence, the required action on the wastewater discharge from the Thilawa Substation should be done to maintain the water quality.

Table 5.2.2-2 Wastewater Quality and Surface Water Quality

Date	Point	Location	pH	Suspended solid (mg/l)	BOD (mg/l)	COD (mg/l)	Oil and Grease (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Total Coliform (MPN/100 ml)
4th May 2017	WW-1	Septic tank outlet within the substation compound	8.6	133	288	588	ND (<5)	18.3	0.58	>160,000
21st July 2017			7.09	101	9.6	20.05	5.65	47.3	8.01	>160,000
21st July 2017	SW-1	In the paddy field, outside the substation compound	6.20	72.2	3.6	16.95	2.26	4.76	0.07	92,000
NEQG General Guideline Value			6-9	50	50	250	10	-	2	400

Source: Environmental Monitoring Report for the Thilawa Substation (May 2017 and July 2017)

3) Noise and Vibration

Noise levels (LA_{eq}) of daytime and nighttime are compared with the target value of "Industrial, Commercial" receptor of Myanmar National Environmental Quality (Emission) Guideline (2015), and the results of package 2 monitoring report (July 2016) and package 3 monitoring report (May 2017) complied with the standard as shown in the following **Table 5.2.2-3**.

Table 5.2.2-3 Noise Level Measurement

Date	Location	Point	Ambient (dBA)		Remark
			Daytime (7:00-22:00)	Nighttime (22:00-7:00)	
15th-16 July 2016	Outside of Thilawa GTG Power Plant Compound	NV-1	66	62	
4th -5th May 2017	Outside of Thilawa Substation Compound, Thilawa SEZ area	NV-1	62	60	Weekday
6th-7th May 2017	Outside of Thilawa Substation Compound, Thilawa SEZ area	NV-1	62	63	Weekend
Target Noise Level in NEQG (Industrial, Commercial)			70	70	

Source: Package 2 Monitoring Report (July 2016) and Package 3 Monitoring Report (May 2017)

5.3 Environmental and Social Consideration on the Project Implementation

5.3.1 Comparison of the Options for Project Implementation

The following options are compared and evaluated from 1) technical, 2) financial, economic, and 3) environmental aspects as shown in the following **Table 5.3.1-1**. The environmental checklist and Environmental Management Plan (EMP) and Environmental Monitoring Plan (EMOP) of the selected option (Option 4) are summarized in **Appendix-1** and **Appendix-2**.

Table 5.3.1-1 Options for Comparison

Item	Option 1	Option 2	Option 3	Option 4
Characteristics	Combined cycle of the existing 2 GTs	Relocation of Ywama NEDO Unit (1GT+1ST)	Relocation and rehabilitation of GT from Ywama NEDO Unit/ Combined cycle of 3 GTs	Option 1 + 2
Composition of the plant GT:G:STG	2:2:1	2:2 (Existing) 1:1:1	3:3:1	2:2:1 + 1:1:1
Additional capacity (MW)	25	32.2	23.2+36.6 =59.8	25+32.2=57.2
Total planned capacity (MW)	75 (Existing 50, New 25)	82.2 (50+32.2)	109.8 (50+59.8)	107.2 (50+57.2)
Estimation of water consumption (ton/day) with ACC and WCC cooling method	250 (ACC) 3,340 (WCC)	83 (ACC) 1,104 (WCC)	375 (ACC) 5,010 (WCC)	333 (ACC) 4,444 (WCC)
Environment (air)	Gas emission from existing 2 GTs can comply with the target level.	It is necessary to check whether combination of gases from rehabilitation of 1 GT & ST from Ywama and existing 2 GTs can comply with the target level for emission or not.		
Environment (water use and ground subsidence)	Difficult to take groundwater due to shortage of groundwater resource and avoidance of ground subsidence. Necessary to take surface water (e.g., reservoir water/river water)			
Social	No resettlement, land acquisition, and income restoration.		No resettlement and land acquisition, and income restoration for existing land use plan of the project (It may be necessary for 1 or 2 households to assist income restoration such as crop compensation in case of using temporary construction yard around the project area)	

Source: Prepared by the JICA Study Team

In order to control the emission gas quality from the relocation of Ywama Facility, the EPGE has a plan to install the dry low NO_x (DLN) combustor during the maintenance process after relocation to the Thilawa Power Plant.

5.3.2 Past Stakeholder Consultation Meetings

Previously, the stakeholder meetings were conducted in each stage of EIA report preparation for Thilawa Power Plant (50 MW) as shown in **Table 5.3.2-1**.

As a requirement of the loan agreement funded by JICA, it is necessary to conduct one stakeholder meeting for the proposed upgrading project during the period of preparatory study. In order to disseminate the information on electricity upgrading project in Thilawa area, one stakeholder meeting was organized as shown in **Table 5.3.2-2** by cooperating with TSMC and EPGE. The related documents of stakeholder meeting such as invitation letter, agenda, handout, presentation material, list of participants, and meeting memo are shown in **Appendix-3**.

Table 5.3.2-1 List of Past Stakeholder Meetings

No.	Description	Month/Year	Remark
1	PCM for 50 MW Power Plant Project (Scoping Stage)	March/2014	*PCM: Public Consultation Meeting
2	PCM for 50 MW Power Plant Project (Draft EIA Stage)	September/2014	
3	Individual Meeting on Crop Compensation Between Surrounding Households (2 households) and Government Organizations (TSMC and MOEE)	February/2015	*TSMC: Thilawa SEZ Management Committee

Source: Prepared by the JICA Study Team

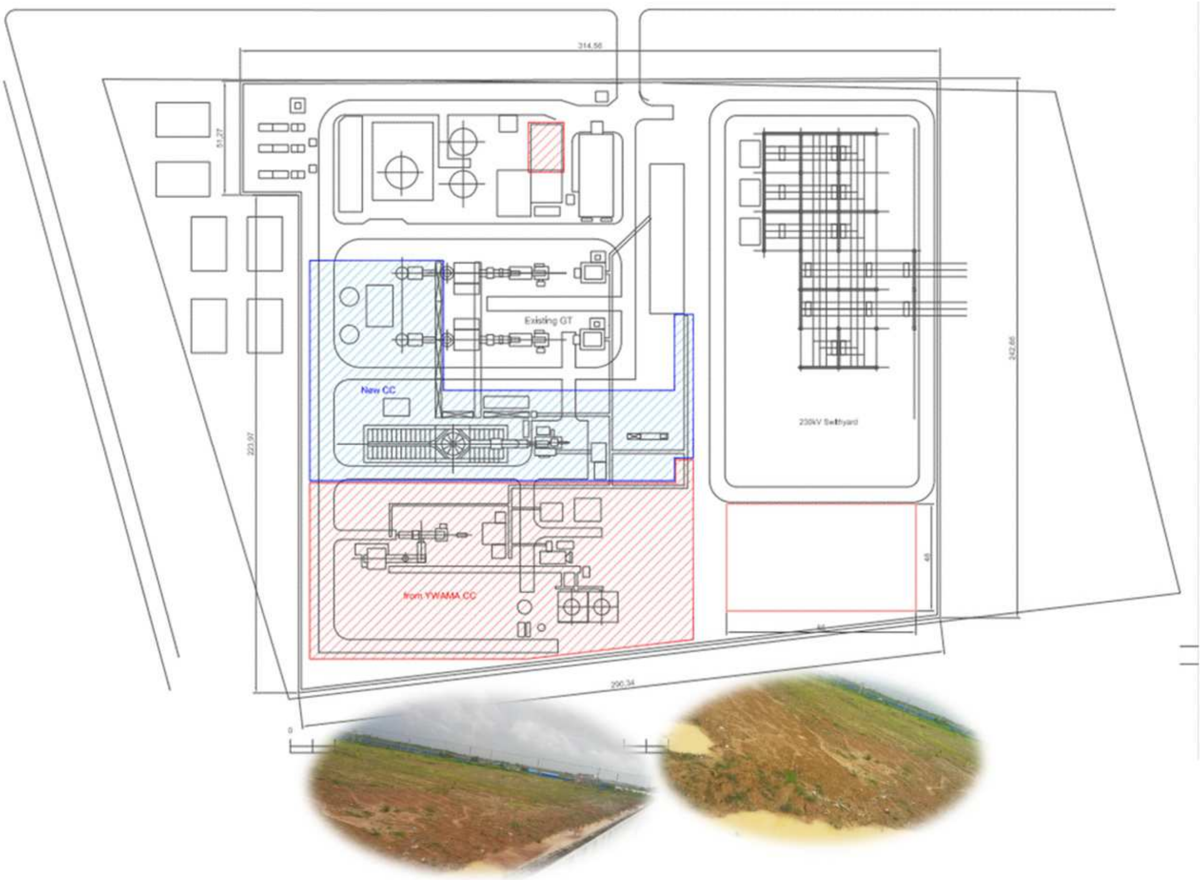
Table 5.3.2-2 Outline of Stakeholder's Meeting

Date	Outline
15 November 2017	**[Method and No. of Meetings]** One meeting in the morning (AM) **[Venue]** Convention Hall, Department of Human Settlement and Housing Development, Thilawa SEZ Management Committee Office (Temporary), Thanlyin Township near Thilawa SEZ **[Agenda]** -Project Description for the Upgrading Project -Major findings in the preparatory study (Thermal and Transmission, Environmental) **[Invited Participants]** 28 persons were participated in the stakeholder meeting from the following organization/ individuals. -Local government in and around the Thilawa SEZ in Thanlyin and Kyauktan townships -Local residents in Thilawa SEZ area -Project proponent (EPGE) and related government organizations (e.g., TSMC) - Developer of Thilawa SEZ (Myanmar Japan Thilawa Ltd.) -Interested individuals **[Invitation Method]** Invitation/notice on the meeting will be posted in township administration office one week in advance. **[Language Used]** The presentation will be in English and the handout in Myanmar language. The explanation will also be translated into Myanmar language. **[Master of Ceremony]** From the viewpoint of consideration of gender equality, the JICA Study Team assigned a lady as the master of ceremony for the stakeholders meeting. **[Special Considerations to Socially Vulnerable Groups]** Feedback forms were provided to participants who are hesitant to speak out in public, through this they can share their views and comments. *Note: Assistants are available to fill out the form in case assistance is needed in writing/reading. Female assistants will be available for female participants who need any assistance.* **[Discussion]** There are no comments related to environmental and social consideration because the existing power plant has already operated. Environmental Conservation Department of the Ministry of Natural Resources and Environmental Conservation made comments that detailed impact assessments such as noise and air quality shall be implemented in the coming EIA study for the upgrading project.

Source: Prepared by the JICA Study Team

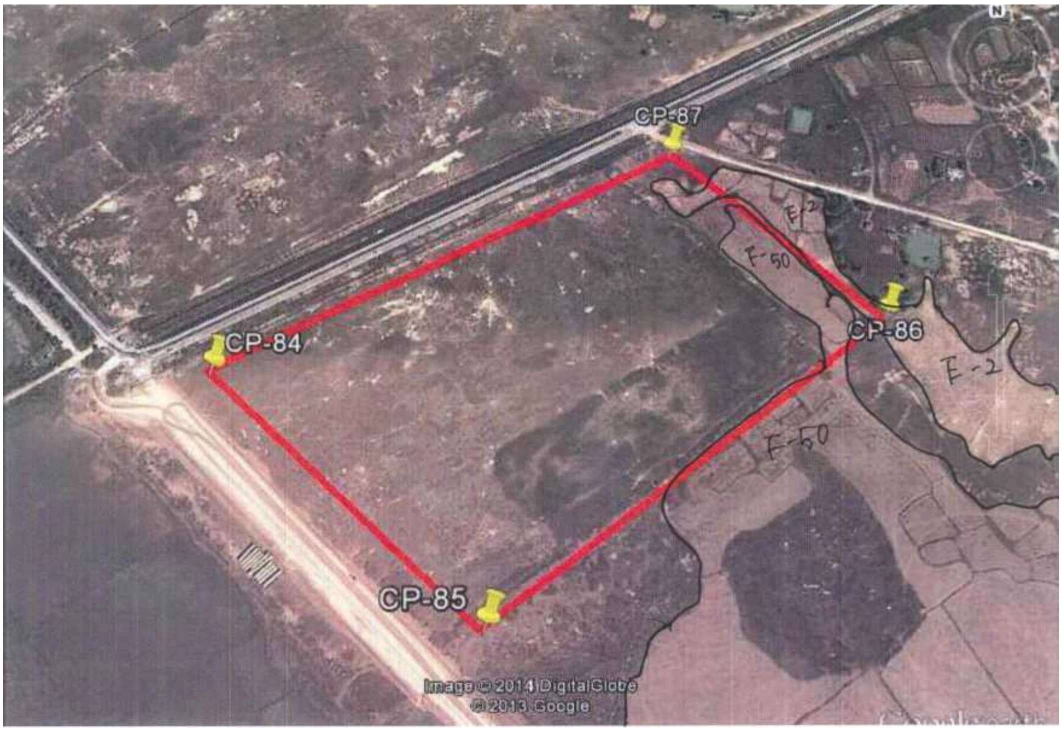
5.3.3 Information of Potential Project Affected Households

The tentative plan for the expansion of project and current condition of land is shown in the following **Figure 5.3.3-1**. Some small areas are to be newly developed when Options 3 or 4 are applied. The Thilawa Power Plant and substation are developed in the area of 10 hectares under the TSMC. Land was compensated in 1998. **Figure 5.3.3-2** shows the boundary of the project site as well as the current cultivation area. If the expansion land has residents cultivating in that area, the TSMC will discuss crop compensation policy based on Resettlement Work Plan for Thilawa SEZ Zone A Development in February 2015.



Source: Prepared by the JICA Study Team

Figure 5.3.3-1 Tentative Plan for Expansion of Project and Status of Surrounding Land



Source: Prepared by the JICA Study Team based on TSMC and Google Earth Pro

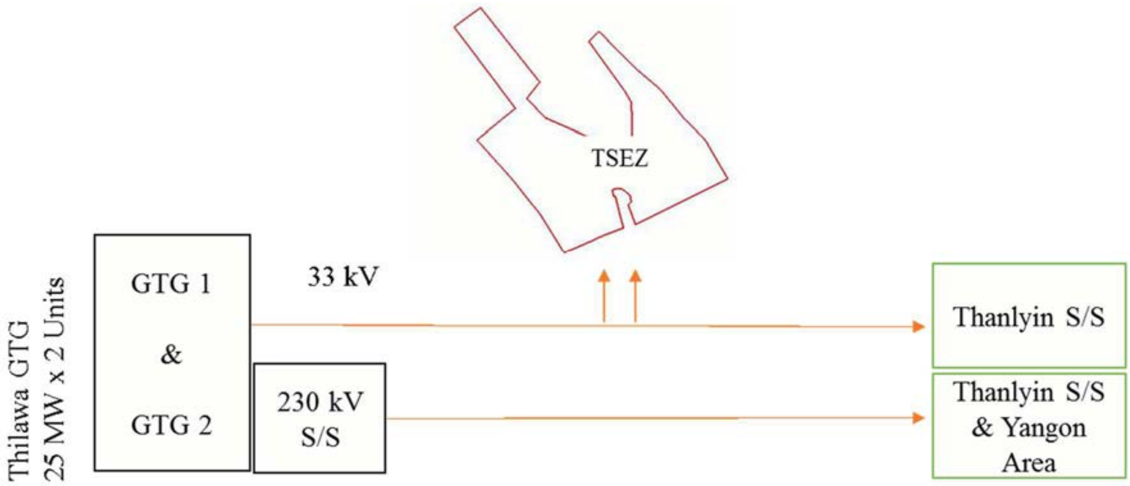
Figure 5.3.3-2 Image of Boundary of 10 Ha Project

5.4 Environmental Performance of the Existing GTG Project

5.4.1 Existing Facilities in the Existing Thilawa GTG Project

1) Power Supply Status

The following schematic diagram (see **Figure 5.4.1-1**) shows the current power supply status near the Thilawa SEZ. The current gas turbine generators (GTG) supply power to the TSEZ with a half capacity of one GTG (12.5 MW) with alternative operation of each unit to provide the demand of TSEZ at about 4.5 to 5.0 MW.



Source: Prepared by the JICA Study Team

Figure 5.4.1-1 Schematic Diagram of the Current Power Supply Status near the Thilawa SEZ Area

The outline specifications of the current GTG in Thilawa Power Plant are shown in the following **Table 5.4.1-1**.

Table 5.4.1-1 Outline Specifications for Gas Turbine Generators

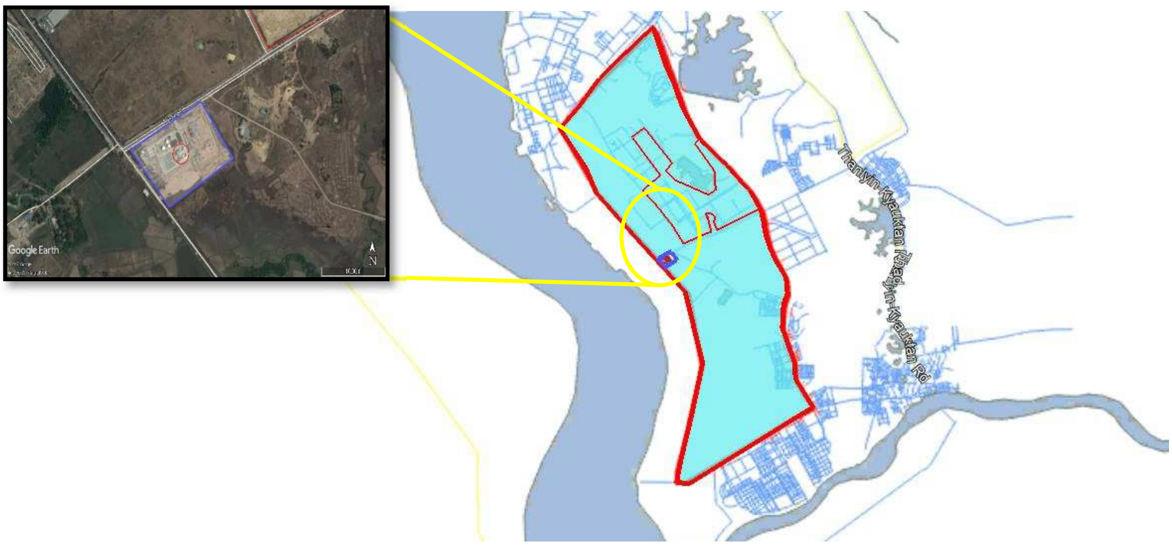
Item	Specifications
Turbine	Simple cycle gas turbine
Gross Output (at Gen end)	50 MW in total (for two units)
Number of units	Two units
Fuel	Diesel oil and natural gas
Thermal Efficiency	Not less than 30%
Construction Period	Total of about 19 months (from Feb 2015 to Sep 2016)
Operation Period	Started from Sep 2016

Source: Draft EIA Report for Thilawa Power Plant (Package 2) and the JICA Study Team

The gas turbine generators are equipped with all the necessary facilities for continuous operation, such as:

a.	Simple cycle gas turbine	2 sets
b.	Generator	2 sets
c.	Gas turbine and generator control system	2 sets
d.	Step-up and auxiliary transformers	2 sets
e.	Stack	2 nos, 1 lot (two turbines)
f.	Fuel tank	
g.	Demineralizer and water tank	1 lot (two turbines)
h.	Special tools for maintenance and start-up spare parts	1 lot (two turbines)
i.	Other peripheral equipment	1 lot

2) Maps of the project site



Source: Prepared by the JICA Study Team

Figure 5.4.1-2 Location Map of the Proposed Project in Thilawa Area

Source: Prepared by the JICA Study Team based on Google Earth Pro

Figure 5.4.1-3 Satellite Image of Site Location

5.4.2 Environmental Performance of the Existing Thilawa Power Plant

1) Emission Gas

In the existing Thilawa Power Plant, heavy duty type gas turbines (Mitsubishi Hitachi Power System) are installed. In order to control gas emission (particularly NO_x) from using gas/liquid fuel, the water injection system has been added in each of the unit of the GTG. This system injects demineralized water into the combustor through the fuel nozzles to regulate the combustor flame temperature and lower NO_x emission. Currently, the water injection system has not been operated yet due to the half load operation of GTGs and lack of water supply (demineralized water) required for the injection system (600 tons/day). On the other hand, the emission without water injection is monitored by a portable gas analyzer (PG-350), Product of HORIBA (see **Figure 5.4.2-1**). Also, the CO_2 Fire Fighting System Room is also installed by connecting the copper tube between the apparatus and measuring probe.

Source: Prepared by the JICA Study Team

Figure 5.4.2-1 Portable Gas Analyzer

Source: Prepared by the JICA Study Team

Figure 5.4.2-2 Installation of CO_2 Fire Fighting System Room

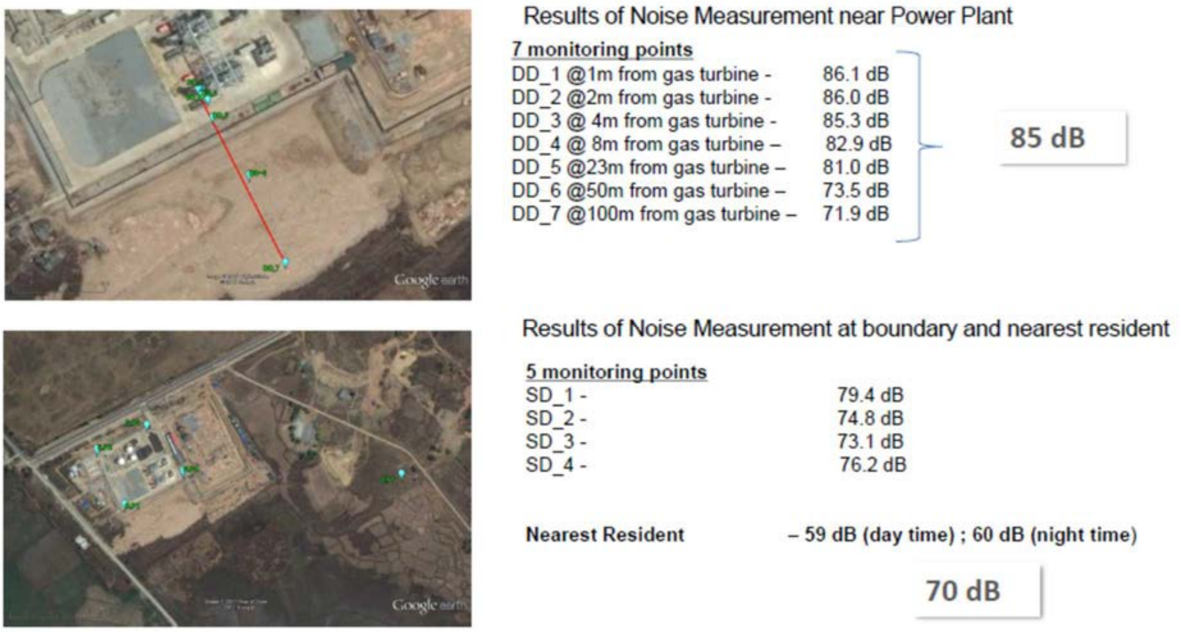
In the measurement of NO_x gas emission from both the GTG units in August 2016, it indicated that NO_x emission at 15% O_2 was about 65.2 ppm for GTG Unit 1 and 62.6 ppm for GTG Unit 2, respectively. The emission gas without water injection was just slightly over the target value of NO_x emission (61 ppm, World Bank Standard) described in the draft EIA report. The NEQG's value for NO_x emission is 49 ppm (100 mg/Nm^3).

In September 2017, the test run with full capacity (50 MW) was implemented with/without water infection, the results of NO_x emission levels were 102-105 ppm (at 15.6-16.0% O_2) without water injection and 25 ppm (at 15 % O_2) with injection for GTC Unit 1 and 111-113 (at 13.5 % O_2) without water injection 24 ppm (at 13.9% O_2) with injection for GTC Unit 2. It was confirmed that NO_x emissions comply with both the World Bank NO_x emission standard (61 ppm) and NEQG NO_x emission level (49 ppm) during water injection. The emission gas monitoring points of each GTC unit are at the duct between gas turbine and chimney.

In case that the operation of upgrading project, the gas turbine from Ywama Power Station does not have water injection system for NO_x reduction, NO_x level from the gas turbine is expected to be at 60 ppm to 110 ppm same as NO_x level of the Thilawa Power Plant without water injection. In case that the average of NO_x level of the Thilawa Power Plant will be confirmed at less than 97 ppm without water injection based on NO_x monitoring data and around 25 ppm with water injection, the average NO_x level will be at 49 ppm (25 ppm each from the two gas turbines in Thilawa and 97 ppm from the gas turbine of Ywama) in compliance with NEQG NO_x emission.

2) Noise

The noise monitoring was implemented on 29 to 30 September 2017 by the consulting team of the Infrastructure Development Project in Thilawa Area Phase I (Power Supply). The target noise level was set at 85 dB for occupational health and safety in the power plant and set at 70 dB for living environmental condition at the nearest houses stipulated in NEQG (industrial and commercial area). As the results of the survey, both noise levels inside of the power plant and at nearest houses complied with the target noise level as shown in **Figure 5.4.2-3**. However, it is necessary to check noise impact and effectiveness of countermeasures such as installation of noise barrier and silencer in case of upgrading the power plant.



Source: Prepared by the JICA Study Team based on the Infrastructure Development Project in Thilawa Area Phase I (Power Supply)

Figure 5.4.2-3 Noise Measurement Results

3) Water Quality

As for treatment of domestic wastewater, septic tank is installed. However, it has not yet confirmed whether the wastewater will comply with the NEQG or not. Thus, it may be necessary to check whether improvement of the existing wastewater system is important or not based on the actual monitoring data.

As for the treatment of wastewater from demineralizer, it has not been confirmed yet whether the wastewater treatment system may be necessary to install or not, because necessity of treatment system is depending on the water to be supplied. Thus, it is recommended to check the necessity of installation of wastewater treatment system for demineralizer based on the actual water quality from Langunbyn Reservoir under the Yen Loan Project of the Yangon Water Supply (Phase 1).

5.5 Demarcation of Myanmar Side for the Project Implementation

When the upgrading of the Thilawa Power Plant Project is started, the following actions/activities should be done from the Myanmar side (e.g., MoEE/EPGE) as shown in **Table 5.5-1**.

Table 5.5-1 Required Activities of MoEE/EPGE

No.	Activities	Remark
1.	Land compensation/resettlement/ income restoration/crop compensation	For the existing 10 ha project area (power plant and substation), TSMC grants usage rights to the MoEE. For future expansion of the land, TSMC and MoEE may cooperate for this activity.
2.	To discuss/negotiate with relevant authorities to use water such as water supply system and reservoir water	
3.	To attend stakeholder meeting, public consultation meetings in the EIA study	
4.	To provide environmental related required information for the upgrading project	
5.	To conduct environmental monitoring and management during operation and maintenance	
6.	To make a greenbelt with trees and/or vegetation covers if land is available.	

Source: Prepared by the JICA Study Team

5.6 Cummulative Impact Asssessment

1) Background

This project is for the upgrading capacity of the power supply from 50 MW to 107 MW and the emission gas will also increase through the installation of additional gas turbine from the existing Ywama Power Plant. Thus, it is important for the project to assess cumulative impact of emission gas quantitively by the installation of an additional gas turbine.

2) Methodology

In order to assess cumulative impact, numerical simulation model named the "Gaussian Plume Model" was applied. The theoretic numerical formula in the model is commonly used in Japan as well as in other developed countries. The model estimates the maximum pollutant concentration emitted by gas turbines based on the information on emission gas, background air concentration, and to assess its impacts in and around the project site. The detailed methodology, condition of numerical simulation model, and its results are summarized in **Appendix-4**.

3) Cases for Cumulative Impact Assessment

The following three cases for numerical simulation are set to assess cumulative impact of NO_x emissions in the upgrading capacity of power supply. The conditions of each case are summarized in **Table 5.6-1**.

Case 0: Existing Condition (50 MW gas turbine without water injection system of the existing Thilawa Power)

Case 1: Future Condition 1 (107 MW combined cycles without water injection system of the existing Thilawa Power and Ywama Gas Turbine)

Case 2: Future Condition 2 (107 MW combined cycles with water injection system of the existing Thilawa Power and Combined Cycle without water injection system of Ywama Gas Turbine)

Table 5.6-1 Conditions of Air Quality Simulation Model

Item	Unit	Case 0	Case 2	Case 3	Note
Capacity of electric supply	MW	50	107	107	
Water injection system to the existing power plant in Thilawa	-	Not applicable	Not Applicable	Applicable	The additional gas turbine from the existing Ywama Power Plant does not have water injection system.
Volume of exhaust gas (dry bases)	Nm^3/h	252,333	252,333 (Thilawa) 246,323 (Ywama)	251,752 (Thilawa) 246,323 (Ywama)	Based on manufacturer's catalog
Temperature of exhaust gas	ºC	559	103 (Thilawa) 559 (Ywama)	103 (Thilawa) 559 (Ywama)	Based on manufacturer's catalog
Wind speed at 10 m	m/s	3.1	3.1	3.1	Based on existing information
Height of the chimney (G.L.+)	m	20	20	20	Average based on existing information
NO_x emission concentration	ppm	260	260 (Thilawa) 260 (Ywama)	61 (Thilawa) 260 (Ywama)	Based on manufacturer's catalog (actual NO_x emission concentrations are less than the catalog's values)

Source: Prepared by the JICA Study Team

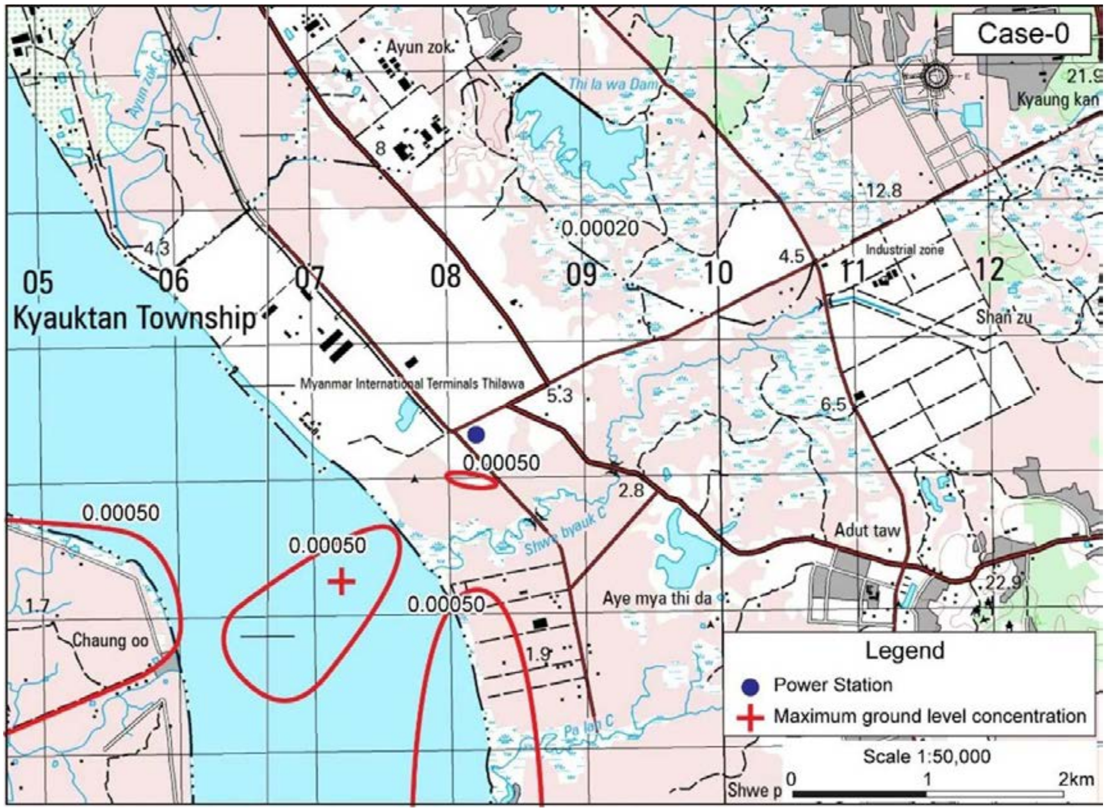
4) Results of Cumulative Impact Assessment

As the result of air quality simulation shown in **Table 5.6-2**, and **Figure 5.6-1**, **Figure 5.6-2** and **Figure 5.6-3**, maximum NO_2 concentrations at ground are 0.03567 ppm in Case 0 (50 MW without water injection system), 0.03788 ppm in Case 1 (107 MW without water injection system), and 0.03788 ppm in Case 2 (107 MW with water injection system). Maximum ambient air quality on the ground in all cases will comply with the target ambient air quality level (0.06 ppm is set as the target level in the existing draft EIA report same as the Japanese standard) and contribution rate is at small percentage. Thus, it was confirmed that cumulative impact on air pollution from the gas turbines will be limited.

Table 5.6-2 Result of the Air Quality Simulation Model

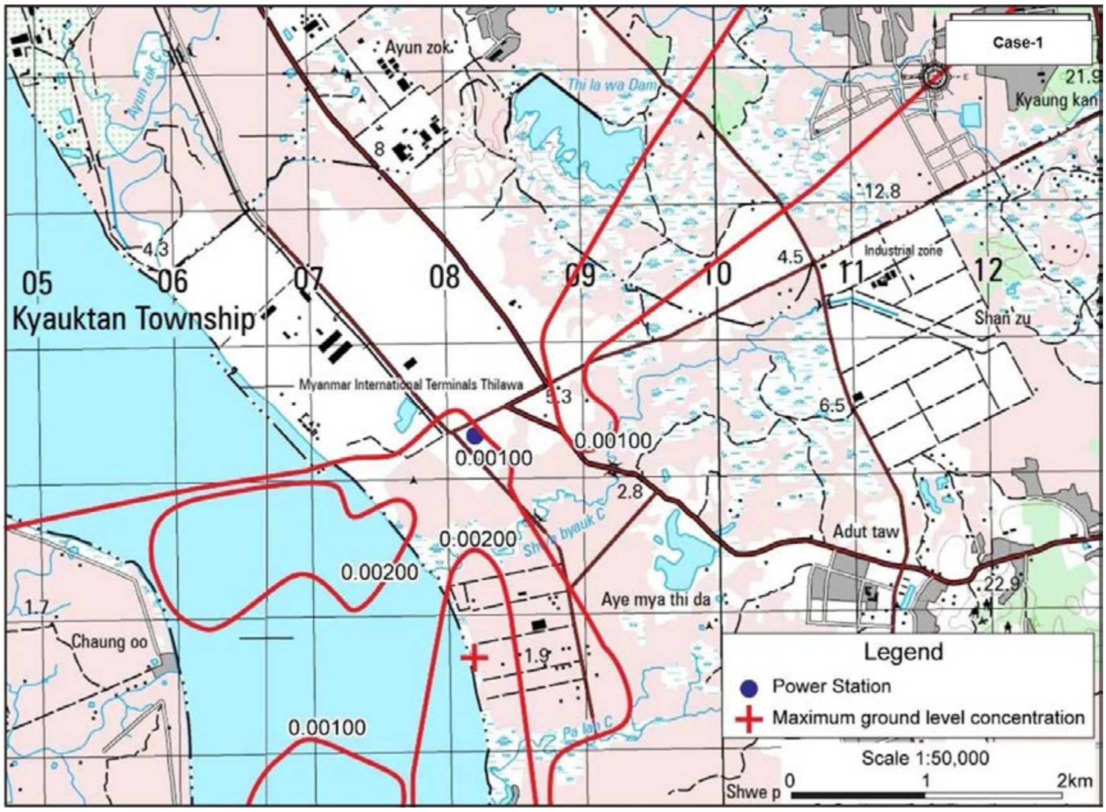
Case	Contribution of Emission Gas (NO_2) by Simulation Model	Background Concentration (NO_2) in 2013	Maximum Ambient Air Quality at Ground (NO_2)	Target Ambient Air Quality Level (NO_2)	Contribution Rate
Case 0 (50 MW without water injection)	0.00067 ppm	0.035 ppm	0.03567 ppm	0.06 ppm (Same as the Japanese Ambient Air Quality Level)	1.9%
Case 1 (107 MW without water injection)	0.00288 ppm		0.03788 ppm		7.6%
Case 2 (107 MW with water injection)	0.00065 ppm		0.03565 ppm		1.8%

Source: Prepared by the JICA Study Team



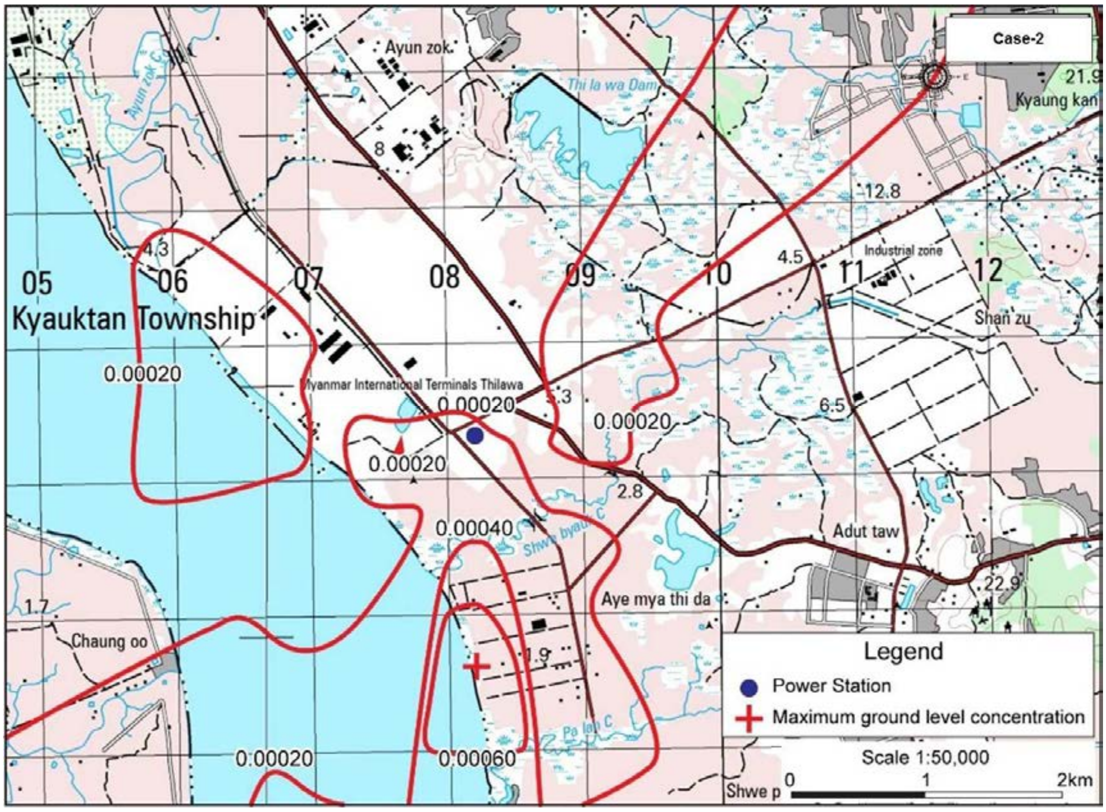
Source: Prepared by the JICA Study Team

Figure 5.6.1-1 NO_2 Concentration at Ground (Case 0: 50 MW without water injection)



Source: Prepared by the JICA Study Team

Figure 5.6.1-2 NO_2 Concentration at Ground (Case 1: 107 MW without water injection)



Source: Prepared by the JICA Study Team

Figure 5.6.1-3 NO_2 Concentration at Ground (Case 2: 107 MW with water injection)

5.7 Issues to be Solved and Recommendation of the Project

1) Assistance of Implementation of EIA Study

As mentioned above, it takes around one year to get an approval of the EIA study from the start of the preparation of the updated EIA report. In case that the EIA approval (including official confirmation of emission gas and noise standards by MONREC-ECD) will be required at the timing before distribution of tender documents to the contractor, it may be necessary to start the preparation of updated EIA report before procurement of consultant for the detailed design or bidding by yen loan. Because MOEE requests JICA to support the preparation of the updated EIA report, it is necessary to consider the timing of the start of preparation and procurement of consultant for the EIA study, if necessary.

2) Application of NO_x Emission Standard

In case that the operation of upgrading project, the gas turbine from Ywama Power Station does not have water injection system for NO_x reduction, NO_x level from the gas turbine is expected to be at 60 ppm to 110 ppm same as NO_x level of the Thilawa Power Plant without water injection. In case that the average of NO_x level of the Thilawa Power Plant will be confirmed at less than 97 ppm without water injection based on enough NO_x monitoring data and around 25 ppm with water injection, the average of NO_x level will be at 49 ppm (25 ppm each from the two gas turbines in Thilawa and 97 ppm from the gas turbine of Ywama) in compliance with NEQG NO_x emission.

NEQG does not mention about detailed application of standards clearly such as application of the NO_x standard to emission of each unit of gas Turbine and to emission of average of the all gas Turbines

(Average will be calculated by dividing total pollution load and total emission gas volume of three units. Pollution load is calculated by multiplying emission gas volume and concentration of emission gas from each unit and total pollution load is adding pollution load from each unit.). Thus, it is necessary to authorize the above standard application by MONREC-ECD through discussion and appraisal process of the final updated EIA report.

3) Monitoring of application of water injection system for NO_x emission reduction in the existing Thilawa Power Plant

As mentioned above, the existing Thilawa Power Plant (25 MW x 2 units) has a function of water injection system to reduce NO_x emission. However, the injection system will be started after the water supply from Langunbyn Reservoir under the Yen Loan Project of Yangon Water Supply (Phase 1). Because water supply for the injection system is an essential point for the project to comply with NO_x emission concentration stipulated in NEQG, it is necessary to monitor the application of water injection system to the existing Thilawa Power Plant.

Chapter 6 Financial and Economic Viability

6.1 Expected Impact of the Project (Operation and Effect Indicators)

Operation indicators are intended to evaluate the operational condition of the Project, which quantitatively checks whether the Project is being operated properly.

Table 6.1-1 Operation Indicators (Option 1)

Indicator	Formula	Target
Plant load factor (%)	= Electricity generated per year / (rated output × hours per year) × 100	80%
Gross thermal efficiency	= (Gross electricity generated per year × 860) / (fuel consumption per year × heat release value of the fuel) × 100	More than 45%

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

Table 6.1-2 Operation Indicators (Option 2)

Indicator	Formula	Target
Plant load factor (%)	= Electricity generated per year / (rated output × hours per year) × 100	80%
Gross thermal efficiency	= (Gross electricity generated per year × 860) / (fuel consumption per year × heat release value of the fuel) × 100	43%

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

Effect indicators are intended to evaluate the outcome of the Project.

Table 6.1-3 Effect Indicators (Option 1)

Indicator	Formula	Target
Net electric energy production (GWh)	As shown by the name of the indicator	175.2 GWh
Maximum output (MW)	As shown by the name of the indicator	25 MW

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

Table 6.1-4 Effect Indicators (Option 2)

Indicator	Formula	Target
Net electric energy production (GWh)	As shown by the name of the indicator	225.7 GWh
Maximum output (MW)	As shown by the name of the indicator	32.2 MW

Source: JICA, "JICA Operational Indicator and Effect Indicator Reference in ODA Loan Projects", July 2014

6.2 Financial and Economic Analysis

6.2.1 Objectives and Methodology of the Financial and Economic Analyses

The financial and economic analyses aim to examine the viability of the Project by calculating the Internal Rate of Return (IRR) and the Net Present Value (NPV) and are conducted for the selected options.

Financial analysis is conducted to evaluate the profitability of the Project from the viewpoint of the implementing organization (i.e., EPGE). To obtain the Financial Internal Rate of Return (FIRR) and the Financial Net Present Value (FNPV), net benefit of the project is calculated considering 1) the benefits i.e., incremental revenue of tariff from the Project and 2) the cost-based on the market price.

Financial cost excludes price escalation, Interest During Construction (IDC), and other financial charges from the project cost. FIRR and FNPV are calculated based on the cash flow before interest payments.

Economic analysis is conducted to evaluate the viability of the Project from the viewpoint of the national economy. To obtain the Economic Internal Rate of Return (EIRR) and the Economic Net Present Value (ENPV), the benefit of the Project is calculated considering 1) the increased benefit based on the saved cost by replacing alternative energy sources (e.g., diesel generators) and 2) the economic costs.

In the EIRR and ENPV calculation, the cost of the Project is converted to economic cost in order to evaluate the actual cost for the national economy. In this regard, the transfer payment within the national economy (e.g., tax) is excluded from the calculation as it is neither a benefit nor a cost for the country.

The cash flow of the Project is prepared to calculate the IRR and NPV. These figures are calculated based on the following formula. The IRR is equal to the cut-off rate that results in zero NPV. For the calculation of the NPV, a predetermined discount rate is used.

$$\sum_{t=1}^{n}\left\{(B-C)_t \div (1+r)^t\right\}=0$$

Where, B=Benefit, C=Cost, t=tth year (1,2,3…n), n=P roject life, r= IRR

For the calculation of both the IRR and NPV, two cases, namely, “with project” and “without project”, are normally considered to determine the net incremental benefit and cost. The foregone benefit of “without project” is not taken into consideration in the analysis in order to estimate the net incremental benefit of the Project as the Project is to be constructed in the site of the existing Thilawa Power Plant and the loss of benefit due to the Project (e.g., agricultural production) is not expected.

6.2.2 Assumptions used in the Financial and Economic Analyses

This section lists and describes major assumptions that are used for calculating IRR and NPV based on the findings in the study.

1) Project Life, Salvage Value, and Price Base

The Project is assumed to have a useful economic life of 30 years for Option 1 and 20 years for Option 2 after the completion of construction as the latter is a rehabilitation project and a shorter project life is applied. At the end of the economic life, the Project is assumed to have no salvage value.[5] Benefits and costs are expressed in terms of 2017 constant prices in Myanmar kyat.

2) Tariff as Financial Benefit

In order to calculate the incremental revenue as the benefit in the financial analysis, the tariff of MMK 105/kWh is used in the calculation of the financial benefit as it can be regarded as the average cost of generation by gas-fired thermal power plant.[6][7]

[5] There may remain some monetary value at the end of operation if the facility and equipment are scraped and sold in the market. However, such possible monetary value is not taken into account for the analysis due to the uncertainty and difficulty in estimating monetary value.
[6] Deloitte, “Myanmar Power Sector Financial Analysis and Viability Action Plan: Key Findings and Recommendations”, May 18, 2016. This presentation analyzes that the tariff for gas-based power plant is close to MMK 105/kWh.
[7] According to a newspaper article, the cost of gas-fired generation reaches up to MMK 143/kWh. Myanmar Times, “Govt mulls plan to raise power tariffs”, August 19, 2017.

In fact, it is at MMK 57/kWh that the Electric Power Generation Enterprise (EPGE) sells the electricity to Yangon Electricity Supply Corporation (YESC) at present.[8] It should be, however, noted that the tariff of MMK 57/kWh reflects the generation cost of not only the thermal power plants but also the hydro power plants, whose generation cost is much cheaper than that of the thermal power plant. The tariff of MMK 57/kWh is not sufficient to cover the initial capital cost and recurrent cost of the Project.[9]

In addition, EPGE does not pay any tariff for the electricity generated from the power plants under EPGE as it is regarded as an inter-organizational transaction. Therefore, the in-depth analysis is conducted in "5.4 Financial Situation of the Organizations in Charge of Generation and Distribution" in order to estimate the financial ability of the Project to generate cash for the repayment of the loan.

3) Operation and Maintenance Cost

Operation and maintenance cost is assumed to be 3% of the EPC cost and will be incurred from the first year of operation.

4) Conversion Factor

The Standard Conversion Factor (SCF) is an indicator to estimate the level of distortion in the market due to policies, duties, or subsidies of the Government of Myanmar. The SCF is applied in the economic analysis when the local cost, which is assumed to be distorted, is to be converted into economic cost in order to eliminate distortion.

The SCF is calculated as 0.99 based on the following formula, and figures from the recent terms of trade and duties. As the figure of SCF is nearly equal to one, it can be concluded that there is little distortion in the prices in the local market.

SCF= [Import (CIF) + Export (FOB)] / [(Import + Import Duty) + (Export + Export Subsidy - Export Tax)]

Table 6.2.2-1 Terms of Trade

(Unit: MMK in million)

Import	Export	Import Duty	Export Tax	Export Subsidy	SCF
12,524	16,633	367	0	0	0.99

Source: Central Statistical Organization, "Myanmar Statistical Yearbook 2016", Table 14.01 Value of Foreign Trade, Table 17.02 Current Receipts of the State Administrative Organizations
Note: Figures in the table are those of FY 2014.
Note: Figure of import duty is converted in kyat by using exchange rate of MMK 1,350 = USD 1.

Regarding labor cost, it is assumed that there are no significant distortions in the wage of skilled labor in the economic analysis. In the case of unskilled labor, although unemployment exists in Myanmar, the percentage of unemployment is 4.0% in 2014.[10] Like the skilled labor, the distortion in the wage of unskilled labor is not assumed in the economic analysis.

8 According to EPGE, the wholesale price of electricity from EPGE to YESC will increase from MMK 57 to 60/kWh from October 2017 based on the approval of the Executive Committee under the Ministry of Electricity and Energy. The tariff to Mandalay Electricity Supply Corporation (MESC) will be raised from MMK 52 to 55/kWh.

9 If MMK 57/kWh is used for calculating the financial benefit, it becomes impossible to calculate IRR in the case of Option 2 as the net cash flow becomes negative in all years of the project life.

10 Central Statistical Organization, "Myanmar Statistical Yearbook 2016", Table 7.02 Labour Force, Labour Participation Rate, Unemployment Rate, Working Age Population, Aggregate Measure of Labour Underutilization (LU-4) and Outside Labour Force. The figure is that of 2014 based on the result of 2014 Myanmar Population and Housing Census (based on 15-64 years).

5) Cut-off Rate

The cut-off rate is used as a deciding factor whether the Project is viable from the viewpoint of the implementing organization and the national economy by comparing it with FIRR and EIRR, respectively.

In principle, the cut-off rate adopted in the financial analysis is calculated based on the concept of opportunity cost of capital. As the financing of the Project is not finalized yet and it is difficult to calculate the weighted average cost of capital, the rate of the treasury bill, which is 8.8%,[11] is used as the opportunity cost of capital.

The Asian Development Bank (ADB) uses 10-12% as the social discount rate for the economic analysis, and such rate is regarded as the social opportunity cost of capital.[12] This report applies 12% for the calculation of ENPV to make the calculation of ENPV conservative.

6) Transmission and Distribution Loss

Transmission loss (3.1%) and distribution loss (11.8%) are applied to calculate the net incremental sales of electricity to the end consumers and the economic benefit in the economic analysis.

Table 6.2.2-2 Transmission and Distribution Loss

Transmission Loss	3.1%
Distribution Loss	11.8%
Transmission and Distribution Loss	**14.9%**

Source: Transmission loss: Deloitte, "Myanmar Power Sector Financial Analysis and Viability Action Plan: Key Findings and Recommendations", May 18, 2016, p. 7; Distribution loss: YESC Statistics (from 2011-2012 to 2015-2016), p.5

Transmission loss is taken into consideration in the financial analysis as the volume of generated electricity sold to YESC is calculated based on the amount that have reached the YESC after transmission.

7) Water

The cost of water is incurred in the financial analysis. Amount of water use is assumed to be 250 tons/day for Option 1 and 83 tons/day for Option 2. The cost of water is calculated based on the assumption of unit cost of water (MMK 2,970/ton).[13]

Table 6.2.2-3 Assumption on the Amount of Water

Option 1	250	tons/day
Option 2	83	tons/day

Source: Prepared by the JICA Study Team

The cost of water is not taken into account in the economic analysis, as it is regarded as a transfer cost between stakeholders within the country.

11 The figure is based on the market weighted average accepted yield of 364-day treasury bill on August 16, 2017.
12 ADB Economics and Development Resource Center, "Guideline for the Economic Analysis of Projects", February 1997, p.37
13 According to the interview with the Yangon City Development Committee (YCDC), YCDC buys water from the Ministry of Irrigation at one cent per gallon. The cost of water for the Project is not yet decided, but the cost of one cent per gallon is tentatively used for calculating the cost.

8) Gas

The cost of gas is incurred to the gas turbine which is relocated from Ywama Power Station and rehabilitated. The unit cost of USD 7.5/MMBtu is applied to calculate the cost of gas. The cost of gas is not incurred to the electricity generated by the steam turbine.

6.2.3 Financial Analysis

In this section, the financial costs for the Project are identified first. Secondly, the financial benefit is identified and quantified. Lastly, based on the assumptions, costs and benefits calculated, the FIRR and FNPV are calculated and presented.

1) Financial Cost

The financial cost is derived from the project cost, which is indicated in the estimate of the project cost. Financial cost consists of 1) initial investment cost and 2) operation and maintenance (O&M) cost.

Project cost includes engineering, procurement, and construction (EPC) cost, consulting services, and physical contingency and price escalation, financial charges, administration, tax and other costs. On the other hand, financial cost is used to estimate the performance of the Project from the viewpoint of the implementing organization, and excludes price escalation and IDC and financial charges from the project cost.

The summary and annual disbursement of the financial cost for the Project are indicated in the tables below.

Table 6.2.3-1 Financial Cost of the Project upon Completion of Construction (Option 1)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Items	Financial Cost		
	F/C	**L/C**	**Total**
EPC cost			
Consulting service			
Price escalation			
Physical contingency			
Subtotal: Eligible Portion			
Subtotal: Non-eligible Portion			
Total			

Source: Prepared by the JICA Study Team

Table 6.2.3-2 Financial Cost of the Project upon Completion of Construction (Option 2)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Items	Financial Cost		
	F/C	L/C	Total
EPC cost			
Consulting service			
Price escalation			
Physical contingency			
Subtotal: Eligible Portion			
Subtotal: Non-eligible Portion			
Total			

Source: Prepared by the JICA Study Team

Table 6.2.3-3 Annual Allocation of Financial Cost (Option 1)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Year	Financial Cost		
	F/C	L/C	Total
Year 1			
Year 2			
Year 3			
Year 4			
Year 5			
Year 6			
Total			

Source: Prepared by the JICA Study Team

Table 6.2.3-4 Annual Allocation of Financial Cost (Option 2)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Year	Financial Cost		
	F/C	L/C	Total
Year 1			
Year 2			
Year 3			
Year 4			
Year 5			
Total			

Source: Prepared by the JICA Study Team

2) Financial Benefit

The financial performance of the Project is evaluated from the viewpoint of the implementing organization (i.e., EPGE). The financial benefit of the Project is identified as the incremental revenues from electricity sales to the distribution company. If the Project starts to operate, the implementing organization can sell more electricity and earn more revenue. The gross generation after the completion of the Project is assumed to reach 400.9 GWh.

Table 6.2.3-5 Expected Generation

	Electricity Generated
Option 1	175.2 GWh (25 MW x 8,760 hours/year x 80%)
Option 2	225.7 GWh (32.2 MW x 8,760 hours/year x 80%)
Total	**400.9 GWh**

Source: Prepared by the JICA Study Team

The benefit is calculated until the end of the project life. For financial analysis, the benefit of incremental revenue can be calculated in a particular year, by multiplying the net incremental generated electricity with the average generation cost (MMK 105/kWh).

$$Incremental\ Revenue = Net\ Incremental\ Generation\ (GWh) \times Tariff\ (Kyat/GWh)$$

Table 6.2.3-6 Financial Benefit of the Project before Discounting (Option 1)

(Unit: GWh, MMK in million)

	1) Gross Incremental Generation	2) Transmission Loss	3) Net Incremental Generation (1-2)	4) Incremental Revenue
Year 6 and onward	175	5	170	17,826

Source: Prepared by the JICA Study Team

Table 6.2.3-7 Financial Benefit of the Project before Discounting (Option 2)

(Unit: GWh, MMK in million)

	1) Gross Incremental Generation	2) Transmission Loss	3) Net Incremental Generation (1-2)	4) Incremental Revenue
Year 6 and onward	226	7	219	22,960

Source: Prepared by the JICA Study Team

3) FIRR and FNPV

Benefit and cost are compiled and calculated considering the 2017 prices in order to obtain the FIRR. Moreover, the rate of the treasury bill (8.8%) is used as the discount rate for calculating the FNPV. By using the discount rate, the FNPV of Option 1 turns into a positive value, while that of Option 2 becomes negative because the gas cost is incurred in the case of Option 2 and a shorter project life (20 years) is applied.

Table 6.2.3-8 FIRR and FNPV

This table is not published at this public edition of the report.

	FIRR	FNPV (MMK in million)	FNPV (USD in million)
Option 1			
Option 2			
Total			

Source: Prepared by the JICA Study Team
Note: FIRR and FNPV of Total (Option 1+Option 2) are calculated based on 30 years of project life.

Sensitivity analysis is conducted for the financial analysis as the actual condition may be different from those assumed for the base case. In the sensitivity analysis, 1) cost increase (+10%) and 2) delay in construction (one year) are considered.

Table 6.2.3-9 Sensitivity Analysis for Financial Analysis (Option 1)

This table is not published at this public edition of the report.

Case	Benefit	Cost	FIRR	FNPV	
			(%)	(MMK in million)	(USD in million)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: Prepared by the JICA Study Team
Note: The cost includes both the financial cost during construction period and O&M cost.

Table 6.2.3-10 Sensitivity Analysis for Financial Analysis (Option 2)

This table is not published at this public edition of the report.

Case	Benefit	Cost	FIRR	FNPV	
			(%)	(MMK in million)	(USD in million)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: Prepared by the JICA Study Team
Note: The cost includes both the financial cost during construction period and O&M cost.

The FNPV of Option 1 remains positive in all cases of sensitivity analysis. On the other hand, the FNPV of Option 2 is negative in all cases of sensitivity analysis, reflecting the fact that incremental gas cost is incurred for Option 2 and it reduces the profit margin.

6.2.4 Economic Analysis

In this section, the economic costs of the Project are identified first. Secondly, the economic benefit is identified and quantified based on the concept of saved cost. Lastly, based on the assumptions, costs and benefits calculated, the EIRR and the ENPV are calculated and presented.

1) Economic Cost

Economic cost is derived from the project cost, which is indicated in the estimation of project cost. Costs of project items in local currency are converted to economic costs by applying the corresponding conversion factors. Costs of items that are already at border price do not need to be adjusted.

Economic cost is used to estimate the performance of the Project from the viewpoint of the national economy, and excludes price escalation, duty and taxes, and interest during construction. Taxes are not included in the economic cost as they are transfer payments within the economy of a country and are not real cost to the national economy.

Table 6.2.4-1 Economic Cost of the Project upon Completion of Construction (Option 1)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Items	Economic Cost		
	F/C	L/C	Total
EPC cost			
Consulting service			
Price escalation			
Physical contingency			
Subtotal: Eligible portion			
Subtotal: Non-eligible portion			
Total			

Source: Prepared by the JICA Study Team

Table 6.2.4-2 Economic Cost of the Project upon Completion of Construction (Option 2)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Items	Economic Cost		
	F/C	L/C	Total
EPC cost			
Consulting service			
Price escalation			
Physical contingency			
Subtotal: Eligible portion			
Subtotal: Non-eligible portion			
Total			

Source: Prepared by the JICA Study Team

Table 6.2.4-3 Annual Allocation of Economic Cost (Option 1)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Year	Economic Cost		
	F/C	L/C	Total
Year 1			
Year 2			
Year 3			
Year 4			
Year 5			
Year 6			
Total			

Source: Prepared by the JICA Study Team

Table 6.2.4-4 Annual Allocation of Economic Cost (Option 2)

This table is not published at this public edition of the report.

(Unit: MMK in million)

Year	Economic Cost		
	F/C	L/C	Total
Year 1			
Year 2			
Year 3			
Year 4			
Year 5			
Total			

Source: Prepared by the JICA Study Team

2) Economic Benefit

In identifying the economic benefit level, the saved cost is calculated from the viewpoint of the national economy, by using the economic cost of alternative energy sources as the upper limit and the tariff as the lower limit. The difference between the upper and lower limit is assumed to be the saved cost, which is the economic benefit.

A) Avoided Cost of Alternative Energy

The cost of two major alternative sources of electricity can be saved by the incremental supply of the electricity generated by the Project. It is assumed in the economic analysis that kerosene lamps are used by residential users as alternative source of lighting and diesel generators are used by industrial and other users.

The recent statistics of YESC shows the user category wise electricity consumption as indicated in the table.

Table 6.2.4-5 Category-wise Electricity Consumption of YESC's Consumers

Unit: GWh

	Domestic	Industrial	Bulk	Other	Total
FY 2015	1,844	1,010	543	2,513	5,910
Share (%)	31.2%	17.1%	9.2%	42.5%	100.0%

Source: YESC Statistics (From 2011-2012 to 2015-2016), Table: Sale of Electricity

B) Diesel Generators

Diesel generators, one of the major alternative sources of power supply, can be replaced by using incremental power supply. The saved cost of replacing diesel generators can be regarded as economic benefit.

The cost of generation by a diesel generator consists of fixed and variable costs. Fixed cost (i.e., purchase cost of equipment) is excluded in the calculation as it is regarded as a sunk cost at the time of calculation.

Table 6.2.4-6 Variable Cost of Generation by Diesel Generator

Item		Figure	Unit
Installed capacity	A=kVA*Power Factor	9.2	kW
Power factor	Power factor = 0.8	0.8	
Load factor	Load factor = 0.5	0.5	
Net generation	B=kW*8,760*Load factor	40,296	kWh/year
Economic cost of diesel oil	C=International price (Ultra-Low-Sulfur No. 2 Diesel Fuel)	559.91	MMK/liter
Fuel consumption	D=Web site info	2.10	L/hour
Fuel cost	E=Fuel consumption (liter per hour)*8,760*Load factor*Fuel price per liter	5,150,077	MMK/year
Variable O&M cost	F=Fuel cost*1%	51,501	MMK/year
Total Cost	**G=E+F**	**5,201,577**	**MMK/year**
Variable cost per kWh	**H=G/B**	**129.08**	**MMK/kWh**

Source: Prepared by the JICA Study Team

As a result of the calculation, MMK 129.08/kWh is decided as the upper limit of the economic cost of diesel generators.

C) Kerosene Lamp

The residential users without access to the grid electricity are assumed to be using kerosene lamps for lighting. Since the purchase cost of kerosene lamps is relatively small, only the variable cost per kWh of kerosene lamps is calculated.

Table 6.2.4-7 Variable Cost of Kerosene Lamp

	Item		Figure	Unit	Remark
A	Equivalent wattage of kerosene lamp	Assumption	40	watt	
B	Hours of use per day	Assumption	3	hours	
C	Equivalent kWh per year	A*B*365/1,000	43.8	kWh/year	
D	Unit price of kerosene	International price	505	MMK/liter	
E	Amount of use per year	Based on web info	54.75	L/year	0.05 L/hr × 3hrs × 365 days
F	Cost of kerosene per year	D*E	27,668	MMK/year	
	Variable cost per unit	**K=J/F**	**631.68**	**MMK/kWh**	

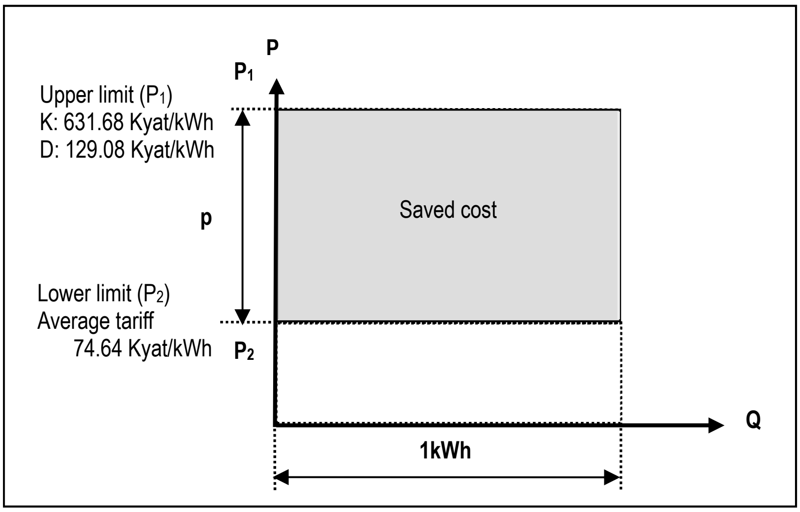
Source: Prepared by the JICA Study Team

As a result of the calculation above, MMK 631.68/kWh is the upper limit of the economic cost of the kerosene lamps.

D) Saved Cost

The saved cost represents the economic value of electricity consumption of the electricity users. In the economic analysis, economic benefits are equated with the savings from using electricity for lighting, industrial, and other works, by utilizing kerosene lamps and diesel generators as major sources of alternative energy.

It is assumed in the analysis that the difference between 1) the weighted average retail tariff and 2) what consumers are actually paying for the alternative source of energy is the saved cost.



Note: "K" represents "Kerosene lamps", while "D" represents diesel generation.
Note: According to YESC Statistics (From 2011-2012 to 2015-2016), the amount of electricity sold is 5,913 million kWh and the revenue of the tariff is 441,331 in FY 2015. Therefore, the revenue realized from consumer per kWh is 74.64 Kyat.

Figure 6.2.4-1 Saved Cost

Based on the share of consumption of each tariff category, the weighted saved cost is calculated at MMK 251.25/kWh.

Table 6.2.4-8 Saved Cost of Alternative Energy Source

Tariff Category	Alternative source	Consumption (GWh)		Economic Price Upper limit	Economic Price Lower limit	Difference (saved cost)	Weighted saved cost
			(a)	(b)	(c)	(d)=(b)-(c)	(e)=(a)*(d)
Domestic	Kerosene lamp	3,764	39%	631.68	74.64	557.05	218.12
Industrial	Diesel generator	4,391	46%	129.08	74.64	54.45	24.87
Others	Diesel generator	1,458	15%	129.08	74.64	54.45	8.26
		9,613	100%			**Total saved cost**	**251.25**

Source: Prepared by the JICA Study Team

It can be concluded that those who use kerosene lamps, off grid electricity, or the electricity generated by the standalone method of generation can save the significant amount of cost for the electricity once they have access to the incremental electricity made possible by the Project.

E) Economic Benefit

Based on the calculated saved cost (MMK 251.25/kWh), the economic benefit of the Project is calculated as shown in the tables below.

Table 6.2.4-9 Gross Economic Benefit of the Project before Discounting (Option 1)

(Unit: GWh, MMK in million)

Year	1) Gross incremental generation	2) Transmission and distribution loss	3) Net distributed electricity (1-2)	4) Incremental economic benefit
Year 6 and onward	175	26	149	37,456

Source: Prepared by the JICA Study Team.

Table 6.2.4-10 Gross Economic Benefit of the Project before Discounting (Option 2)

(Unit: GWh, MMK in million)

Year	1) Gross Incremental Generation	2) Transmission and Distribution Loss	3) Net Distributed Electricity (1-2)	4) Incremental Economic Benefit
Year 6 and onward	226	34	192	48,243

Source: Prepared by the JICA Study Team.

3) EIRR and ENPV

Based on the assumptions, costs and benefits calculated and described so far, the EIRR and ENPV are calculated and presented in this section.

The economic benefit and cost are compiled and calculated in order to obtain EIRR and are discounted using the social discount rate (12%) for attaining the ENPV.

Table 6.2.4-11 EIRR and ENPV

This table is not published at this public edition of the report.

	EIRR	ENPV (MMK in million)	ENPV (USD in million)
Option 1			
Option 2			
Total			

Source: Prepared by the JICA Study Team
Note: EIRR and ENPV of Total (Option 1+Option 2) are calculated based on 30 years of the project life.

The result shows that EIRR of both options is higher than the cut-off rate in the base case. The ENPV of the Project of both options shows a positive result. It can be concluded that the economic benefit of the Project is robust as the people in Myanmar are paying high costs for alternative energy sources (i.e., diesel generators and kerosene lamp) due to insufficient supply of electricity and the Project can be justified from the viewpoint of improving the national economy.

The sensitivity analysis is conducted for economic analysis. The cost increase and delay in construction are considered.

Table 6.2.4-12 Sensitivity Analysis for Economic Analysis (Option 1)

This table is not published at this public edition of the report.

Case	Benefit	Cost	EIRR	ENPV	
			(%)	(MMK in million)	(USD in million)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: Prepared by the JICA Study Team
Note: The cost includes both the economic cost during construction period and O&M cost.

Table 6.2.4-13 Sensitivity Analysis for Economic Analysis (Option 2)

This table is not published at this public edition of the report.

Case	Benefit	Cost	EIRR	ENPV	
			(%)	(MMK in million)	(USD in million)
Base case	No change	No change			
Cost increase (+10%)	No change	+10%			
Delay in construction (1 year)	No change	No change			

Source: Prepared by the JICA Study Team.
Note: The cost includes both the economic cost during construction period and O&M cost.

In Option 1 and Option 2, the impact on EIRR and ENPV of the change in the level of cost and delay in construction is small with slight change of EIRR and ENPV.

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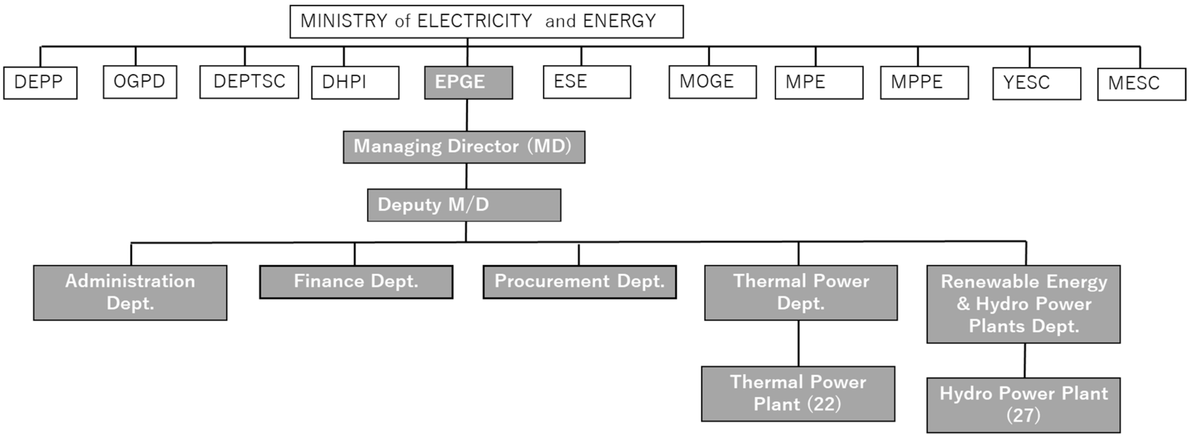
Chapter 7 Capability of the Government of Myanmar for the Project

7.1 Overview of the Implementation Organization

EPGE

The Thilawa Power Plant is under the management of Electric Power Generation Enterprise (EPGE), which is one of enterprises under MOEE. EPGE is expected to be the implementation organization. The organizational structures of MOEE and EPGE are shown in **Figure 7.1-1**.

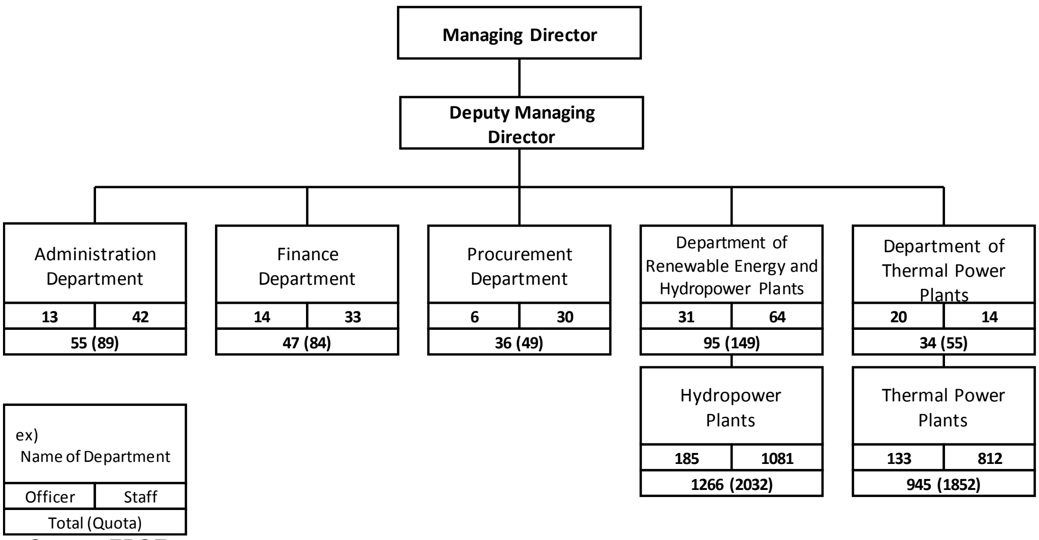


Source: EPGE

Figure 7.1-1 Organizational Structure of MOEE and EPGE

As shown in the figure, EPGE has three administration sections, one department for thermal power and one department for hydropower plants. The thermal power department and hydropower power department are also in-charge of power purchase of IPPs' power.

The total number of the staff in EPGE is 2,478, as of August 2017. Out of the total number of staff, 402 staffs are ranked as officer, 1,345 staffs are technical staff, and 748 staffs are for administration. The number of staffs who has more than a bachelor's degree is 1,084. The organizational structure of EPGE with the number of staff is shown in **Figure 7.1-2**.



Source: EPGE

Figure 7.1-2 Organization Structure of EPGE and Number of Staff in Each Department

The figures in the parentheses are quotas of the staff. The quota of officer is 576 persons, but currently, the number is just 402 persons. The total number of staff excluding officers are 2,076 persons, while the quota of it is 4,310 persons.

7.2 Organizational Chart for the Project Implementation

As mentioned in Section 7.1 and shown in **Figure 7.1-1** (Organizational Structure of MOEE and EPGE) in Section 7.1, EPGE will be an implementation organization and MOEE will be a responsible organization.

Experience in Design and Construction

The gas-fired power plants under EPGE control are Hlawga, Ywama, Ahlone, Thaketa, and Thilawa in Yangon Region, and seven plants outside of the Yangon Region. These gas fired power plants were constructed under EPC contract. Under the EPC contract, the employer, i.e., EPGE, specifies the necessary function and output of the plant. Designing, procurement, manufacturing, and installation/construction are done by the contractors under their responsibilities. Therefore, EPGE has no experience in designing, procurement, and installation of gas-fired generators. If these items are under the responsibility of EPGE, it is necessary to utilize external resources.

Experience in the Operation and Maintenance

The gas fired power plants owned by EPGE are directly managed by EPGE and its staff. Especially, thermal power plants of Kyunchaung, Myanaung, and Thaton were constructed in the 1970s and operated for more than 40 years. EPGE has much experience in operation and maintenance.

To avoid the incident at the Ywama Power Plant, which is now an idle equipment after the trouble, technical assistance is very effective especially proper monitoring of the status of machine and preventive maintenance concept.

7.3 Study on Capability of EPGE for the Project Implementation

In Myanmar, stable supply of thermal power is an important issue in order to cope with tightness of electricity demand.

For stable supply of electric power, an appropriate management system at each power plant is required and that necessary spare parts and measurement equipment for maintaining the equipment should be available.

Next, from a technical point of view, daily inspections and periodic inspections (GT combustor inspection and GT full inspection, etc.) · Equipment diagnosis (deterioration diagnosis and remaining life diagnosis) · Preventive maintenance · Improvement maintenance are planned and implemented. These activities are important to be done.

In the survey, the Study Team visited EPGE''s thermal power station and conducted a hearing on the situation, in a limited time. Based on an interview survey from the EPGE Power Station and stakeholders, the following points were discussed. The survey execution dates of each power plant are as follows:

- Ywama August 30, 2017
- Thilawa August 23, 2017

- Ahlone August 31, 2017
- Hlawga October 7, 2017
- Thaketa October 7, 2017
- Toyo-Thai August 31, 2017

Management system of the thermal power station

For each power plant, the head of the director is the top and the structure of the technician is largely constructed. In addition, technical documents necessary for the operation are in place.

Concerning the operating techniques and maintenance technology of the power plant, the JICA Study Team confirmed whether know-how has been handed over from experienced engineers to young engineers, and as a result, basically, the technology has been handed down through on-the-job (OJT) within the power plant.

Although there was no time to directly check the detailed data such as daily driving record, record of periodic inspection, repair record, repair plan, etc., it was said that periodical report to EPGE was done.

Status of power generation equipment

Gas turbine power generation equipment as main equipment is installed outdoors. Since the gas turbine main body is contained in the package, the influence of the environment is small, but in case of checking the combustor, it is worrisome to do the work outdoor using outdoor installation crane. Especially during the rainy season (May-October) in Myanmar, there may be sudden thunderstorms, so there is a concern about the influence at the time of checking the combustor. Naturally, curing of disassembly equipment at the time of full-scale inspection is also an important matter.

As for electrical equipment and control equipment, as it is usually installed indoors, there is nothing to worry about in particular.

Status of maintenance of power generation equipment

Thilawa Power Station

Looking at the Thilawa Power Plant, which is the object of this project, only about a year and a half have elapsed since two gas turbines were installed, there is no problem with the maintenance management status of facilities at the present time.

Initially, the fuel gas pressure supplied from EPGE was low, and the gas turbine could only produce half of the output, but the fuel gas compressor was newly installed (as of the end of September) and the performance is being confirmed.

Ywama Power Station

Combined cycle power generation facilities to be relocated (one gas turbine and one steam turbine) are currently installed. **Figure 7.3-1** shows gas turbine and HRSG.

Source: Prepared by the JICA Study Team

Figure 7.3-1 Photo of Ywama's Gas Turbine and HRSG

The power station started its operation in 2004, major overhaul was implemented on April 1, 2013. After the morning of April 19, 2014 (operation time is 38,000 hours), gas turbine trouble occurred and operation has stopped now.

Three and a half years have already passed since the suspension, but the power generating facilities remain neglected, and no maintenance inspections and maintenance have been done to prevent the deterioration of facilities.

For example, when the bottom of a cylinder of a fire extinguishing facility advances corrosion and carbon dioxide is maintained at high pressure and it is dangerous if an explosion accident occurs.

Figure 7.3-2 shows the bottom of corrosive carbon dioxide fire extinguisher cylinder.

From this point of view, the JICA Study Team doubted about the maintenance and management of the power generation equipment, which is the property possessed by EPGE.

It is necessary for future discussions to be made whether the EPGE side can think that maintenance and management of the dormant facilities are also important properties.

Source: Prepared by the JICA Study Team

Figure 7.3-2 Photo of the Bottom of Corrosive Carbon Dioxide Fire Extinguisher Cylinder

<u>Accident prevention measures in the operation of gas turbine</u>

Considering the damage accident of the gas turbine installed in the Thilawa Power Station, introduction of the "Monitoring System in Japan" of gas turbine operation should help prevent accidents. Monitoring of gas turbines of power generation equipment is an important operation support system, as with jet engine monitoring of aircraft. In order to introduce this system, various sensors are added to the power generation facility, and the information is transmitted to Japan for monitoring. If an abnormality occurs during monitoring, you can obtain advice from Japan in a timely manner.

This system introduction requires a contract and costs, but it also makes it possible to extend the timing of gas turbine combustor inspection and major inspection, so maintenance and management costs can be expected to be reduced. In this regard, the JICA Study Team recommended to consider examining cost effectiveness. The most important thing is that if a mistake is made in the operation of the power generation facility, the expensive power generation equipment will be damaged and a large repair cost will be generated. It is inferred that the merit of introducing "Monitoring system in Japan" is high if this repair cost also puts economic effects.

7.4 Training in Japan (if necessary)

Both in the Thilawa Power Station and the Ywama Power Station, gas turbine power generation facilities were manufactured in Japan. If upgrading both the capacity of this Thilawa Power Plant and the relocation project from the Ywama Power Station are conducted by the Japanese Team, it is conceivable that the Japanese side will provide a comprehensive support from the Japanese side on management of the entire power plant.

For example, guidance on improvement points of daily inspection/periodic inspection and technology transfer of facility diagnosis method of power generation facility are assumed. In addition, technical guidance for improving awareness of preventive maintenance and improved maintenance of power generation equipment is also effective. However, this technical guidance will be examined concretely at the time of request of the power station on the EPGE side and desire of the top on EPGE.

Currently, EPGE does not prepare a training program, and operating and maintenance are situations with training by OJT at each power station. Therefore, support in the preparation of training plan is also effective.

The JICA Study Team examined examples of support contents as follows:

When the plan of reinforcement of Thilawa Power Plant is realized, the JICA Study Team thinks that the method of using timing effectively and providing support is efficient.

Preparation and operation support of educational program

EPGE currently owns five thermal power plants, but if a sharp rise in electricity demand in the Yangon area is anticipated, further expansion of the thermal power plant will be necessary. This movement will require the operation staff of the power plant and reinforcement of maintenance personnel.

Education program as EPGE is necessary because it is difficult to develop systematically and efficiently on-site OJT only. The JICA Study Team thinks that it is effective to support this program creation reflecting the technology and experience in Japan. The creation of the educational program starts with grasping the current situation of EPGE.

Next, the JICA Study Team will proceed with the drafting of the educational program in collaboration with EPGE based on the plan of reinforcement of operation and maintenance personnel on the prediction of future construction of the power plant. Since the operation of the created program is carried out by the lecturer of EPGE, it is necessary to provide support as necessary, until the educational program is established steadily.

Election of candidate lecturers and training in Japan

The educational program is implemented through teaching materials (text) based on the educational program, but prior to that, training of lecturers precedes.

First of all, the JICA Study Team selects a qualified candidate to be the instructor candidate jointly with EPGE, and advances the teaching materials (text) making to the lecturer candidate as the key man.

It is planned that the lecturer candidate will go through a training in Japan to have knowledge on the design philosophy of the thermal power generation equipment, operation situation, state of maintenance inspection checked, and acquire basic knowledge.

The educational program begins with teaching materials given to the lecturer candidate in order to be able to understand the specific program operation method through practical training in simulated classes and operation and maintenance work.

Education for field technicians concerning maintenance and inspection

Education for the maintenance and inspection should be carried out according to the actual GT combustor inspection and full-scale inspection of the combined power generation facility in the Yangon area.

In the curriculum of candidate instructors, it is effective to implement in situations where the Japanese engineers participate.

Here, the JICA Study Team introduces advanced technologies such as inspection tips, life diagnosis and facility diagnosis, and also provides comment on the effectiveness of the monitoring services in Japan from the economic point of view, and update the latest situation to the field technician. Stakeholders have the opportunity to get it grasped.

Also, the JICA Study Team will mention the importance of technical communication with Japan and expect to contribute to the construction of network.

Contents of the educational program (draft) and support the work flow (draft)

For the contents described above, **Figure 7.4-1** shows the technical work training support work flow. It is necessary to discuss how to proceed actually based on the present situation of EPGE, the desire concerning the training of technicians in the future, and the voice of the workplace.

Figure 7.4-2 shows the technical training program (draft). An outline of the event in the process of training engineers and educational program is described.

These tables can be used as the basis for proceeding with the consultations such as the number of target persons, place of implementation, and timing of implementation.

1	Understanding situation (step 1)	●Understand the situation of current OJT education and rotation education ● Understanding the situation of education related documents and examining how to utilize it
2	Discussion of education program (draft)	●Discussion with EPGE on how to build educational system (Plan for reinforcement of operation maintenance personnel and plan for nurturing lecturers)
3	Selection of keeper person (Selection of candidate teacher)	●Choose the right person as the lecturer candidate from the field (Choose who can tell "heart" to cherish power generation equipment)
4	Support for educational text making	●Support text making before simulated lessons are carried out (Collaboration between instructor candidate and Japanese lecturer)
5	Executing a classroom / simulated lesson (Step 2)	●Implementation of simulated lessons (Lecturer candidate + students conducted by Japanese instructors)
6	Training in Japan (Step 3)	●Training for instructor candidates in Japan (Tour of maintenance situation at design and manufacturing sites and customers)
7	On-site training (Step 4)	●Field training at GT combustor inspection or full-scale inspection (Teaching from the Japanese instructor to the EPGE lecturer candidate) (Indicates the method of information exchange with Japanese companies)
8	Creating an educational program (step 5)	●Completed the educational program based on the collaborative work thus far (Improve the plan by negotiating with EPGE and complete it)
9	Follow up (step 6)	●Confirmation of the operation status of the educational program and suggestions for improvement (Discuss the operation situation of half a year to 1 year, find out the improvement point)

Source: Prepared by the JICA Study Team

Figure 7.4-1 Technical Training Work Flow (Draft)

Step 1 Grasping the training situation of thermal power generation engineers in EPGE (survey) / 13 days

■ Target: Hearing from EPGE Nay Pyi Taw technician and each power plant technician

	CONTENTS	PLACE	TIME
①	Current status of fostering new engineers	EPGE	2Days
②	Current status and direction of EPGE's educational policy	EPGE	1Day
③	Facts about OJT in power plants	Power plant	5Days
④	Rotation between power stations and improvement of technology	Power plant	2Days
⑤	Request of person in charge in each department	EPGE · Each power plant	3Days

Step 2 Education on Combined Cycle Power Generation Facility (Meeting) / 32 hours × 2 times

■ Target: Each power plant engineer and EPGE Nay Pyi Taw engineer 20 to 30 people

	CONTENTS	PLACE	TIME
①	History of gas turbine and history of thermal power generation	Suburb of Yangon	4Hour
②	Enhance output and efficiency of combined cycle power generation equipment	Suburb of Yangon	4Hour
③	Trend of future combined cycle power generation equipment	Suburb of Yangon	4Hour
④	History of research and development and future direction	Suburb of Yangon	4Hour
⑤	Operation know-how of combined cycle power generation equipment	Suburb of Yangon	4Hour
⑥	Inspection practices and techniques of gas turbines	Suburb of Yangon	4Hour
⑦	Training "heart" that loves power generation equipment and "save money"	Suburb of Yangon	4Hour
⑧	Equipment diagnosis · Lifespan diagnosis and improved maintenance	Suburb of Yangon	4Hour

Step 3 Training in Japan on Combined Cycle Power Generation Facilities / 10 days × 2 times

■ Target: 10 mid-level engineers (5 men, 5 females) / 6 machines and 4 others

	CONTENTS		TIME
①	Design policy of power generation equipment by designers Explanation	Production factory in Japan	4Days
②	Factory tour (at the gas turbine manufacturing factory)	Production factory in Japan	1Day
③	Current status of maintenance inspection (periodic inspection at power station)	Power plant in Japan	2Days
④	Risk reduction site due to central monitoring on power generation facilities	Monitoring system in Japan	1Day
⑤	Grasping the situation of large customers (building demands etc.)	Large domestic customers in Japan	1Day
⑥	Visit the state-of-the-art thermal power plant (coal fired power etc.)	Power plant in Japan	1Day

Step 4 Practice on maintenance on actual machine / 8 days × 2 times

■ Target: Each power plant engineer and EPGE Nay Pyi Taw engineer 15 to 20 people

	CONTENTS	PLACE	TIME
①	Inspection & maintenance work at the time of checking the combustor	Power plant	3Days
②	Inspection & maintenance work of incidental facilities	Power plant	2Days
③	Planning for lifespan diagnosis, facility diagnosis, improved maintenance	Power plant	1Day
④	Information exchange with Japanese companies and efficient power plant operation	Power plant	1Day
⑤	Training "heart" that loves power generation equipment and "save money"	Power plant	1Day

Step 5 Creation / operation support of educational program (collaborative work) / 35days

■ EPGE Nay Pyi Taw Engineers and Power Plant Engineers

	CONTENTS	PLACE	TIME
①	Support for creation of new employee education program	EPGE · Each power plant	7Days
②	Support for creating driving skill improvement programs	EPGE · Each power plant	7Days
③	Inspection maintenance / maintenance improvement program creation support	EPGE · Each power plant	7Days
④	Lifespan diagnosis / Facility diagnosis technology improvement program creation support	EPGE · Each power plant	7Days
⑤	Support for program operation	EPGE · Each power plant	7Days

Step 6 Support for consolidation of education program (Follow-up work) / 8 days x 2 times

■ EPGE Nay Pyi Taw technician and each power plant technician · · · Step 6 After

	CONTENTS	PLACE	TIME
①	Understand the operational status of each program	EPGE · Each power plant	2Days
②	Discussion and discussion on improvement of each program	EPGE · Each power plant	3Days
③	Support for improvement of each program	EPGE · Each power plant	3Days

Source: Prepared by the JICA Study Team

Figure 7.4-2 Technical Training Program (Draft)

Other suggestions

The above engineer training program is planned to be carried out at a power station where the combined cycle power generation facilities of the Yangon area are installed. Therefore, in order to smoothly carry out these implementation training, it is recommended that plans should hold spare parts of gas turbines for about ten years.

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Appendix-1

Environmental Check List

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
Conducting 1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports been already prepared in official process? (b) Have EIA reports been approved by authorities of the host country's government? (c) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) N (b) N (c) - (d) -	(a) The EIA procedures in Myanmar was promulgated in Dec 2015 by MOECAF (Currently, Ministry of Natural Resources and Environmental Conservation. Draft EIA report for existing GTGs (50MW) was prepared. Only the updating of the draft EIA is required for proposed upgrading project and it has not been prepared yet. (b) EIA report for upgrading project has not been submitted and approved yet. (c) It is not yet confirmed. (d) It is not yet confirmed.
	(2) Explanation to the Local Stakeholders	(a) Have contents of the project and the potential impacts been adequately explained to the Local stakeholders based on appropriate procedures, including information disclosure? Is understanding obtained from the Local stakeholders? (b) Have the comment from the stakeholders (such as local residents) been reflected to the project design?	(a) N (b) -	(a) Stakeholder meeting for upgrading project will organize in the November 2017.It has been planning to arrange the Stakeholder meeting with the currently applied appropriate procedures in Thilawa SEZ area. (b) The comments from the Stakeholders will definitely reflect in the project design.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) Y	(a)Alternative plans of the project have been examined with environmental considerations and social considerations as well as simultaneously with technical, financial and economic aspects.
2 Pollution Control	(1) Air Quality	(a) Do air pollutants, such as sulfur oxides (SOx), nitrogen oxides (NOx), and soot and dust emitted by the power plant operations comply with the country's emission standards? Is there a possibility that air pollutants emitted from the project will cause areas that do not comply with the country's ambient air quality standards? Are any mitigating measures taken? (b) In the case of coal-fired power plants, is there a possibility that fugitive dust from the coal piles, coal handling facilities, and dust from the coal ash disposal sites will cause air pollution? Are adequate measures taken to prevent the air pollution?	(a) Y (b) N	(a)National Environmental Quality (Emission) Guidelines have been established in December 2015 in Myanmar. Air pollutant (nitrogen oxides (NOx)) emitted by the power plant operations comply with the National Environmental Quality (Emission) Guidelines now. The project proponent is assured that gas emission from current GTGs will be complied with NEQG guideline values (100mg/Nm3 for NOx) due to applying of water injection system. For relocation of Ywama GTGs, the dry low NOx combustor (or water injection system) will be installed to the GTGs as a mitigation measure. Impacts of air pollutants by the project will be limit because the power plant is small scale and have use gas turbine. (b)The project is not applicable because the project have use gas turbine.
	(2) Water Quality	(a) Do effluents including thermal effluents from the power plant comply with the country's effluent standards? Is there a possibility that the effluents from the project will cause areas that do not comply with the country's ambient water quality standards or cause any significant temperature rise in the receiving waters? (b) In the case of coal-fired power plants, do leachates from the coal piles and coal ash disposal sites comply with the country's effluent standards? (c) Are adequate measures taken to prevent contamination of surface water, soil, groundwater, and seawater by the effluents?	(a) Y (b) N (c) N	(a) The country's effluent standards has been formulated in National Environmental Quality (Emission) Guidelines by MONREC for plant wastewater (from demineralization plant) and sanitary wastewater. The effluent water from the project will comply with the NEQG guidelines. Planned power plant is small scale and has use gas turbines. Thermal effluents are not expected because water for combined cycle will recycle as much as possible. (b) The project is not applicable because the project will apply gas turbine and steam turbine. (c) The project is not applicable because the project will apply gas turbine and steam turbine.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(3) Wastes	(a) Are wastes, (such as waste oils, and waste chemical agents), coal ash, and by-product gypsum from flue gas desulfurization generated by the power plant operations properly treated and disposed of in accordance with the country's regulations?	(a) Y	(a) Wastes such as waste oils waste chemical agents may arise, however, significant impact is not expected because the wastes will be possible to manage within the facility and by waste treatment facility of Yangon City Development Committee (YCDC) and/ or available solid waste management facility inside Thilawa Special Economic Zone.
	(4) Noise and Vibration	(a) Do noise and vibrations comply with the country's standards?	(a) Y	(a) The country's noise standard has been formulated in National Environmental Quality (Emission) Guidelines by MONREC. Noise will comply with the NEQG Guidelines. Although noise and vibration by operation will arise, significant impact is not expected because there is enough distance from the source to residential area. On the other hand, the impact of continuous low frequency noise level on the residential area far from the project is likely to be considered.
	(5) Subsidence	(a) In the case of extraction of a large volume of groundwater, is there a possibility that the extraction of groundwater will cause subsidence?	(a) N	(a) Not applicable. The project does not include large volume extraction of groundwater.
	(6) Odor	(a) Are there any odor sources? Are adequate odor control measures taken?	(a) N	(a) Not applicable. The project does not include odor souse such as de-nitration process. Only odor from general waste from operation building and workshop will be arisen but it is not so significant odor impact.
3 Natural Environment	(1) Protected Areas	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)?	(a) N	(a) No protected areas designated by laws or international treaties and conventions of the country in and adjacent the project site.
	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? (d) Is there a possibility that the amount of water (e.g., surface water, groundwater) used by the project will adversely affect aquatic environments, such as rivers? Are adequate measures taken to reduce the impacts on aquatic environments, such as aquatic organisms? (e) Is there a possibility that discharge of thermal effluents, intake of a large volume of cooling water or discharge of leachates will adversely affect the ecosystem of surrounding water areas?	(a) N (b) N (c) - (d) N (e) N	(a) No primeval forests, tropical rain forests, ecologically valuable habitats in and adjacent the site. (b) There is no habitat of endangered species that require protection by law or international treaties and conventions of the country in the project site or is vicinity. There is no record of endangered species in IUCN Red list found in the project site or is vicinity in accordance with the EIA study for Zone A and Zone B Development by Myanmar and Japan Thilawa Ltd. (the developer of SEZ). (c) Significant impact is not expected. (d) Significant impact on aquatic environment is not expected because wastewater from the Project will be treated. Thus, significant impact on aquatic organisms is not expected. (e) There is little possibility of thermal water discharge to affect significant impact on aquatic ecosystem because water of heat recovery steam generator (HRSG) will be circulated and only drainage for maintenance will be occurred.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(1) Resettlement	(a) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlement assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Are the compensations going to be paid prior to the resettlement? (e) Are the compensation policies prepared in document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (i) Are any plans developed to monitor the impacts of resettlement? (j) Is the grievance redress mechanism established?	(a) - (b) - (c) - (d) - (e) - (f) - (g) - (h) - (i) - (j) -	Involuntary resettlement by the project will not be arisen.
	(2) Living and Livelihood	(a) Is there a possibility that the project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary? (b) Is sufficient infrastructure (e.g., hospitals, schools, and roads) available for the project implementation? If the existing infrastructure is insufficient, are any plans developed to construct new infrastructure or improve the existing infrastructure? (c) Is there a possibility that large vehicles traffic for transportation of materials, such as raw materials and products will have impacts on traffic in the surrounding areas, impede the movement of inhabitants, and any cause risks to pedestrians? (d) Is there a possibility that diseases, including infectious diseases, such as HIV, will be brought due to the immigration of workers associated with the project? Are adequate considerations given to public health, if necessary? (e) Is there a possibility that the amount of water used (e.g., surface water, groundwater) and discharge of thermal effluents by the project will adversely affect existing water uses and uses of water areas (especially fishery)?	(a) N (b) Y (c) N (d) Y (e) N	(a) The project will cause increase of employment in and surrounding area in collaboration with the industrial zone development. Significant impact on living conditions of inhabitants is not expected because there is enough distance from project site to residential area. Only in case that land expansion is required and cultivation is found around project site (government land), crop compensation may be required (but only one or two households). (b) The project is thermal plant, does not include any infrastructure project. (c) There is little volume of heavy vehicle traffic comparing with existing traffic volume. (d)Although the project will not include large scale construction work, infectious diseases by immigration of workers might arise. Therefore, project proponent will provide thorough instruction in environmental education for construction workers. (e) There is little possibility of thermal water discharge to affect significant impact on fishery because water of heat recovery steam generator (HRSG) will be circulated and only drainage for maintenance will be occurred.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(3) Heritage	(a) Is there a possibility that the project will damage the local archaeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the country's laws?	(a) N	(a) No local archaeological, historical, cultural, and religious heritage in the project area.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a) There are no view landscapes and landscape resources affected in and around the project site.
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) - (b) -	There are no ethic minorities and indigenous people in and around the project area.
	(6) Working Conditions	(a) Is the project proponent not violating any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are appropriate measures taken to ensure that security guards involved in the project not to violate safety of other individuals involved, or local residents?	(a) Y (b) Y (c) Y (d) Y	(a) The project proponent will observe the laws and ordinances associated with working conditions of the country and EHS guidelines of International Finance Corporation. (b) For individuals involved in the project, tangible safety considerations such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials will be implemented. (c) For individuals involved in the project, intangible measures such as establishment of a safety and health program, and safety training (including traffic safety and public health) for workers will be implemented. (d) Appropriate measures such as safety training will be implemented in order to ensure that security guards involved in the project not to violate safety of other individuals involved, or local residents.
5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce the impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce the impacts?	(a) Y (b) N (c) N	(a) Mitigation measures for impacts by construction works (noise, vibration, turbid water, dust, exhaust gases and waste) is prepared in Environmental Management Plan. (b) Significant impact on natural environment is not expected because in and around project area is grassland/farm land and important species was not confirmed. In addition, significant impact on terrestrial ecosystem because the construction of the power facility will not cause habitat disjuncture. (c) Significant impact on social environment is not anticipated during construction phase.
	(2) Accident Prevention Measures	(a) In the case of coal-fired power plants, are adequate measures planned to prevent spontaneous combustion at the coal piles (e.g., sprinkler systems)?	(a) -	(a) Not applicable.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(3) Monitoring	(a) Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts? (b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) - (c) Y (d) Y	(a) Monitoring by project proponent for potential impact items will be planned and conducted adequately. (b) Items, methods and frequencies of the monitoring program is decided based on prior occurrence of EIA and knowledge of expert. (c) Monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework) of project proponent will be planned and conducted adequately. (d) EIA procedures ordained the format and frequency of the monitoring report (two times in a year) in environmental monitoring plan, thus, project proponent should set the methods later.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Thermal Power Plant checklist should also be checked (e.g., projects including installation of electric transmission lines and/or electric distribution facilities). (b) Where necessary, pertinent items described in the Ports and Harbors checklist should also be checked (e.g., projects including construction of port and harbor facilities).	(a) Y (b) -	(a) The thermal power plant checklist was prepared. (b)Not applicable.
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, and global warming).	(a) -	(a) Positive impact on climate change by greenhouse gas effect is anticipated due to installation of heat recovery steam generator (HRSG).

1) Regarding the term "Country's Standards" mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are requested to be made.

In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan's experience).

Appendix-2

EMP and EMOP

Environmental Management Plan (EMP) and Environmental Monitoring Plan (EMOP) for the Project on Improvement of Electricity Supply in Thilawa Area

1. OBJECTIVE OF ENVIRONMENTAL MANAGEMENT PLAN (EMP)

The purpose of the EMP is clarified mitigation measures and its monitoring to be implemented during construction phase by the contractor and during operation phase by Electric Power Generation Enterprise (EPGE) as the Project Proponent in the Project for Improvement of Electricity Supply in Thilawa Area (hereafter called “the upgrading Project”). The EMP will be updated based on the updated Environmental Impact Assessment (EIA) Report for the upgrading Project to be certified.

The EMP shall be reviewed during all phases to verify that mitigation measures in the EMP are duly targeted to minimize the negative impact on natural and social environment in the project areas and then revised as appropriate. This iterative process shall continue throughout all phases.

2. LAW REQUIREMENT

The project owner (EPGE), construction contractor, his sub-contractors, all persons employed on site and any other person authorized to be on site shall be responsible for the full compliance with the following laws, regulations and / or guidelines with respect.

a) Electricity Law (2014)

b) Rules and Regulations of Electricity Law (1985)

c) Myanmar Special Economic Zone Law (2011)

d) Myanmar Special Economic Zone Rules (2015)

e) Environmental Conservation Law (2012)

f) Environmental Conservation Rules (2014)

g) EIA Procedure (2015)

h) National Environmental Quality (Emission) Guidelines (2015)

i) The Conservation of Water resources and Rivers law (2006)

j) The Protection of Wildlife and Conservation of Natural Areas Law (1994)

k) The Forest Law (1992)

l) Freshwater Fisheries Law (1991)

m) Law on Aquaculture (1989)

n) Irrigation Laws and Regulations (1982)

o) Farmland Law (2012)

p) Farmland Rules (2012)

q) Public Health Law (1972)

r) Underground Water Act (1930)

s) Social Security Law (2012)

t) Natural Disaster Management Law (2013)

u) Myanmar Fire-brigade Law (2015)

3. ENVIRONMENTAL STANDARD, DESIGN CRITERIA AND TRAGRT VALUE FOR ENVIRONMENTAL MANAGEMENT IN CONSTRUCTION PHASE

3.1 Environmental Standard in Myanmar

According to the Environmental Conservation Law, MONREC shall set standards of environmental qualities as agreed by the Union Government and the Environmental Conservation Committee. Standards to be set by MONREC are as follows:

(a) standard quality of water related to the use of inland water available to public places, dams, ponds, swamps, flooded land, channel, creeks and rivers
(b) standard quality of water at coastal regions and delta area
(c) standard quality of groundwater
(d) standard quality of air
(e) standard of noise and vibration
(f) standard of odor and emission gas
(g) standard of wastewater

(h) standard of soil and leachate from solid waste

(d) other standard environment qualities set by the Union Government

As of October 2017, these standards have not been set yet. However National Environmental Quality (Emission) Guidelines (NEQGs) enacted by MONREC in December 2015 applies to new and/or expansion of projects which are required to implement EIA/ IEE study. Therefore, the EMP set quantitative target levels based on the NEQGs. The applied target levels are emission, water quality, and noise in operation phase as design criteria, water quality and, noise in construction phase. These are elements which may cause adverse impact to surrounding environment or occupational health and safety, thus quantitative target levels were set each quantitative target level to be applied for the upgrading Project is described below.

3.2 Design Criteria for Environmental Management

3.2.1 Emission Gas

Design criteria of emission gas of the upgrading Project are set based on NEQGs (100 mg/Nm3) as shown Table 3.1 taking into consideration on international guidelines, and standards in ASEAN countries, Japan as well as EU and USA. The target level of emission gas is more than IFC EHS Guidelines (50 mg/N3 in Non-Degraded airshed) but less than the values of the Pollution the Prevention and Abatement Handbook (PPAH) prepared by World Bank (125 mg/Nm3), Japanese Emission Gas Standard (70 ppm (143 mg/Nm3) dry at 15% oxygen), and other ASEAN countries such as Vietnam, Thailand, and Indonesia.

Table 3.1 Target Level of Emission Gas

Parameters	Fuel	Value	Note	Source
Nitrogen Oxides (NO_2)	Natural Gas	100 mg/Nm^3 (49 ppm)	In Non-degraded airshed Dry at 15% oxygen	NEQGs

3.2.2 Water Quality

Design criteria of wastewater effluent of the upgrading Project refers to NEQGs in both construction and operation phases. As for industrial wastewater treatment, target parameters and its values are applied based on characteristics of discharge from thermal plant stipulated in NEQGs as shown in Table 3.2.

As for wastewater treatment by operation building and construction site, target parameters and its values are also applied based on characteristics of discharge from sanitary wastewater discharges stipulated in NEQGs as shown in Table 3.3 basically. As exceptions, total nitrogen and total phosphorus are excluded from the target parameters of the upgrading Project at this moment taking into account of the best available technology of the sanitary wastewater treatment in Myanmar and possibility of eutrophication impact by rich nitrogen and phosphorus at the downstream of discharging points[1].

Table 3.2 Target Water Quality Level (Industrial Wastewater)

No	Items	Value
1.	As	0.5mg/L
2.	Cd	0.1mg/L
3.	Total Cr	0.5 mg/L
4.	Cu	0.5mg/L
5.	Fe	1mg/L
6.	Pb	0.5mg/L
7.	Hg	0.005mg/L
8.	Oil & Grease	10mg/L
9.	pH	6-9
10.	Temperature Increase	less than 3° C
11.	Total residual chlorine	less than 0.2mg/L
12.	Total suspended solids	50 mg/L
13.	Zn	1mg/L

Table 3.3 Target Water Quality Level (Sanitary Wastewater)

No	Items	Value
1.	BOD	30 mg/L
2.	COD	250 mg/L
3.	Oil and grease	10 mg/L
4.	pH Value	6-9
5.	Total coliform bacteria	400 MPN/100mL
6.	Total Suspended Solids	50 mg/L

3.2.3 Noise in Operation Phase

(1) Target Noise Level at Boundary of the Building of the Gas Turbine

Design criteria of noise at boundary of the building (1m from distance) of the gas turbine at operation phase are set based on the General Environmental Health and Safety (EHS) Guidelines by International Finance Cooperation (IFC) as shown in Table 3.4.

[1] Eutrophication impact caused by rich nitrogen and phosphorus are not expected because discharged wastewater will reach to Yangon River directly without retention and distance from the discharge points to Yangon River is less than 2 km.

Table 3.4 Target Noise Level at Boundary of the Building of the Gas Turbine

Item	Target Level (Leq)	Source
Target noise level at boundary of the building of the gas turbine	85 dB	IFC EHS Guidelines

Note: Evaluation point is at boundary of buildings (1m)

(2) Target Noise Level to the Surrounding Area

Design criteria of noise to surrounding area of the upgrading Project at operation phase are set based on EIA Report for Thilawa Special Economic Zone (SEZ) Development Project (Zone B) which was approved by Ministry of Natural Resources and Environmental Conservation (MONREC) and Thilwa SEZ Management Committee (TSMC). The target level of noise and vibration to surrounding area is set in accordance with the approved EIA report as shown in Table 3.5.

Table 3.5 Target Noise Level at Operation Phase

Category	Day time (Leq) (7am-7pm)	Evening Time (Leq) (7pm-10pm)	Night time (Leq) (10pm-7am)
Commercial and Industrial Areas	70 dB	65 dB	60 dB

Note: Evaluation point is at nearest houses (500 m from the gas turbines)

3.2.4 Land Elevation for Prevention of Flood

As well as shown in Section 3.2.4, design criteria of land elevation for prevention of flood of the upgrading Project are set based on the approved EIA Report as shown in Table 3.6.

Table 3.6 Target Land Elevation Level

Target level	Description	Note
E.L. + 5.5m	Storm surge simulation in Yangon river (Cyclone Nargis case)	The target elevation is higher than 1) Hearing survey of flood disaster：E.L. +5.5m and 2) Flood analysis (100years return rainfall)：E.L. +4.9m

3.3 Target Value for Environmental Management in Construction Phase

3.3.1 Noise and Vibration

As well as shown in Section 3.2.4, the target level of noise and vibration to surrounding area is set in accordance with the approved EIA report as shown in Table 3.7 and Table 3.8.

Table 3.7 Target Noise Level in Construction Phase

Category	Day time (Leq) (7am-7pm)	Evening Time (Leq) (7pm-10pm)	Night time (Leq) (10pm-7am)
Residential houses and monastery located more than 150m from the construction site, office, commercial facilities, and factories	75 dB	65 dB	65 dB

Note: Evaluation point is at nearest houses (500 m from the gas turbines)

Table 3.8 Target Vibration Level at Construction Phase

Category	Day time (La) (7am-7pm)	Evening Time (La) (7pm-10pm)	Night time (La) (10pm-7am)
Office, commercial facilities, and factories	70 dB	70 dB	65 dB

Note: Evaluation point is at nearest houses (500 m from the gas turbines)

4. ENVIRONMENTAL MANAGEMENT PLAN (EMP) IN CONSTRUCTION PHASE

4.1 Pollution Control

The contractor shall implement environmental management plan for pollution control such as air quality, water quality, waste, noise, and vibration as shown in Table 4.1. The cost for implementation of environmental management shall be expensed by the contractor.

Table 4.1 Environmental Management Plan (Pollution Control)

Item	Evaluation of Impact	Mitigation and Improvement Measures	Implementation Schedule
Air Quality	Dust and emission gas from construction work and transportation of construction vehicle are anticipated.	- Sprinkle water to prevent dust impact in dry season - Prohibition of idling will be implemented. - Intensive operating of the construction machinery will be avoided. - Construction equipment, machines and vehicle will be inspected and maintained regularly.	Throughout construction period
Water Quality	Muddy water inflow to river from bare land of construction site may deteriorate water quality.	- Settling ponds or simple turbid water treatment will be installed to prevent muddy inflowing to paddy fields, river, creek as necessary.	Throughout construction period
	Discharge from the lodging of construction may deteriorate water quality.	- Septic tank to comply with target level will be set up in construction site or all wastewater from construction site will be stored and collected by waste treatment service companies/ organizations.	Throughout construction period
	Discharge from the wastewater from construction work may deteriorate water quality.	- Simple wastewater treatment facility from cement producing activity will be set up in construction site.	Throughout construction period
Waste	Impact on solid waste may be occurred by generation of waste by excavation, removal work structures will be sorted out to be reused as much as possible and the rest will be treated in the disposal field.	- Recycling of construction soil, materials, general waste as much as possible - Waste storage area with segregation function shall be secured in the site. - Rest of waste shall be disposed to dumping site of municipalities and/ or waste treatment service company. - Appropriate disposal of removed work piece	Throughout construction period
	Impact on hazardous waste will be anticipated if spillages of hazardous wastes and drainage	- Record of usage of hazardous and chemical substance will be prepared and updated regularly.	Throughout construction period

Item	Evaluation of Impact	Mitigation and Improvement Measures	Implementation Schedule
	away without treatment occur.	- Hazardous and chemical substance to be disposed will be stored at the designated storage area and entrusted to the waste treatment service company in Thilawa SEZ.	
Noise and Vibration	Noise and vibration impact is estimated as small due to more than enough distance from construction site to the nearest residence. Noise and vibration from transportation of construction vehicle are anticipated. However, this is a temporary matter and the impact may be limited.	- Advance notice of operations at night time to residence - obey maximum driving speed	Throughout construction period

4.2 Natural Environment Mitigation

The contractor shall implement environmental management plan for natural environmental mitigation such as flora, fauna, ecosystem, and landscape in Table 4.2. The cost for implementation of environmental management shall be expensed by the contractor.

Table 4.2 Environmental Management Plan (Natural Environment Mitigation)

Item	Evaluation	Mitigation and Improvement Measures	Implementation Schedule
Flora and Fauna, Ecosystem	Impact on flora and fauna, ecosystem is not assumed. Area around the site is pasture and agricultural land, and important species of animals and plants have not been identified.	- Planting trees, vegetation, sodding to the open space.	Before completion of construction
Landscape	Impact on landscape is not expected because there are no important landscapes and viewpoints to be considered around the project area.	- Planting trees along road and residential side to mitigate feeling of visual pressure	Before completion of construction

4.3 Social Impact Mitigation

The contractor shall implement environmental management plan for social impact mitigation such as poor, local economy, gender, and children’s right in Table 4.3. The cost for implementation of environmental management shall be expensed by the contractor.

Table 4.3 Environmental Management Plan (Social Impact Mitigation)

Item	Evaluation	Mitigation and Improvement Measures	Implementation Schedule
Poor	Employment residents and poverty group in the area as construction worker is expected to contribute to vitalize regional economy and income increase of the poor.	- The contractor shall contribute to regional economy such as hiring worker from surrounding area within the limitation of the contractors' capability.	Throughout construction period
Local economy such as employment and livelihood	Employment of community people in the area as construction worker and procurement of fuel and food for workers from the area expected to contribute to vitalize regional economy and income increase of the poor.	- The contractor shall contribute to regional economy such as hiring worker from surrounding area within the limitation of the contractors' capability.	Throughout construction period
Gender and Children's Right	Negative impact on gender and children's right is not anticipated.	- The contractor shall not caused impact on gender and children right.	Throughout construction period

4.4 Occupational Health and Safety

The contractor shall implement environmental management plan for occupational health and safety for general mitigation measures and mitigation measures related to construction of thermal plant in Table 4.4. The cost for implementation of environmental management shall be expensed by the contractor.

Table 4.4 Environmental Management Plan (Occupational Health and Safety)

Item	Evaluation	Mitigation and Improvement Measures	Implementation Schedule
General occupational health and safety for construction activity	Accidents and health impact to construction workers are expected with a fixed probability. Working conditions and safety of construction shall be considered.	- Working condition during construction will be managed by contractor based on OHS training stipulated in international guidelines such as EHS Guidelines by IFC as follows; * Provision of adequate healthcare facilities (first aid) within construction sites; * Training of all construction workers in basic sanitation and healthcare issues, general health and safety matters, and on the specific hazards of their work; * Personal protection equipment for workers, such as safety boots, helmets, gloves, protective clothing, spectacles and ear protection; * Clean drinking water facilities for all workers; * Adequate protection to the general	Throughout construction period

Item	Evaluation	Mitigation and Improvement Measures	Implementation Schedule
		public, including safety barriers and marking of hazardous areas; * Safe access across the construction site; * Adequate drainage throughout the camp to ensure that disease vectors such as stagnant water bodies and puddles do not form; * Septic tank and garbage bins will be set up in construction site, which will be regularly cleared by the contractors to prevent outbreak of diseases, and * Where feasible the contractor will arrange the temporary integration of waste collection from work sites into existing waste collection systems and disposal facilities of nearby communities.	
Occupational health and safety for construction of thermal plant	Accidents and health impact to construction workers are expected with a fixed probability. Working conditions and safety of construction shall be considered.	Working condition during construction will be managed by contractor based on OHS training stipulated in international guidelines such as EHS Guidelines for thermal plant by IFC as follows; * Heat prevention (in test operation) * Noise prevention (in construction phase and test operation) * Proper method to enter confined space (in test operation) * Electrical hazards management (in test operation) * Fire and explosion hazards management (in test operation) * Chemical hazards management (in test case) * Dust prevention (in construction and test case)	Throughout construction period and test operation
Risk for infectious disease such as AIDS/HIV	Risks of infectious disease are expected with a fixed probability. Preventive measures against infectious disease shall be considered.	- The following measures of infectious disease will be implemented as necessary. * Prevention of infectious disease from spreading * Training to workers	Throughout construction period

4.5 Community Health and Safety

The contractor shall implement environmental management plan for community health and safety for general mitigation measures and mitigation measures related to construction of thermal plant in Table 4.5. The cost for implementation of environmental management shall be expensed by the contractor.

Table 4.5 Environmental Management Plan (Community Health and Safety)

Item	Evaluation	Mitigation and Improvement Measures	Implementation Schedule
General community health and safety for construction activity	Accidents and health impact to community are expected with a fixed probability. Community health and safety shall be considered.	- Community health and safety will be managed by the contractor based on international guidelines such as EHS Guidelines by IFC as follows; * Protection of the community from physical, chemical, or other hazards associated with sites under construction and decommissioning. * Avoid contact with hazardous materials, contaminated soils and other environmental media, buildings that are vacant or under construction, or excavations and structures which may pose falling and entrapment hazards * The incidence of road accidents involving project vehicles during construction should be minimized through a combination of education and awareness-raising	Throughout construction period
Community health and safety for construction of thermal plant	Accidents and health impact to community are expected with a fixed probability. Community health and safety shall be considered.	Community health and safety will be managed by the contractor based on international guidelines such as EHS Guidelines for thermal plant by IFC as follows; * Not compromise availability of water for personal hygiene, agriculture, and other community needs (in construction phase and test operation) * Ensuring traffic safety to community on transportation of fuel and other materials (in construction phase and test operation)	Throughout construction period and test operation
Risk for infectious disease such as AIDS/HIV	Risks of infectious disease are expected with a fixed probability. Preventive measures against infectious disease shall be considered.	- The following measures of infectious disease will be implemented as necessary. * Prevention of infectious disease from spreading * Communication with local resident including lecture	Throughout construction period

5. ENVIRONMENTAL MANAGEMENT PLAN (EMP) IN OPERATION PHASE

The Project Proponent (EPGE) shall implement environmental management plan to manage/ control pollution, natural environment, social impact, health impact, emergency risks related to operation of the improved thermal plant in Table 5.1. The cost for implementation of environmental management shall be expensed by the Project Proponent.

Table 5.1 Environmental Management Plan (Pollution and Natural Environment)

Category	Item	Mitigation and Consideration Measures
Pollution, Natural Environment	Air pollution	- NOx Reduction System will be installed to comply with target level for NOx emission. - Monitoring of emission gas (NOx) and ambient air quality (NO2)
	Water pollution	- Installation of wastewater treatment system (or storage tank) to comply with target level for water quality - Monitoring wastewater quality at discharging point from wastewater treatment plant will be implemented.
	Hazardous substance management/ Solid Waste/ Soil contamination	- Hazardous material will be controlled and managed (secure proper storage with ventilation, temperature control, and lock, limitation of persons to enter storage, regular recording). - Sludge of wastewater treatment from office and will be disposed to the controlled landfill site. - Prevention of solid and liquid waste from infiltrating into ground to avoid soil contamination and groundwater contamination.
	Noise	- Noise control techniques such as using acoustic machine enclosures, mufflers, silencers, sound absorptive materials in walls and ceilings will be installed to comply with the target noise level. - Monitoring of noise and vibration
	Subsidence	- Monitoring of water use from wells and ground level will be implemented in case of using groundwater.
	Flora and Fauna, Ecosystem	- Maintenance of planted trees, vegetation, and sodding in the open space will be implemented.
	Global Warming	- Procurement of efficient energy consumption type combined cycle shall be installed to minimize GHGs emission. - Fuel Good combustion system will be installed.
Social Impact	Water Use	- Same as mitigation and consideration measures for Subsidence
Health Impact	Occupational health and safety including accidents and infection disease	- Consideration of working conditions will be implemented based on requirement of Occupational Health and Safety (OHS) stipulated in international guidelines such as EHS Guidelines by IFC. Heat prevention Noise prevention Proper method to enter confined space Electrical hazards management Fire and explosion hazards management Chemical hazards management Dust prevention - Measures of infectious disease will be implemented as follows; Plan for prevention of infectious disease from spreading

Category	Item	Mitigation and Consideration Measures
		- Training to workers
	Community health and safety including accidents and infection disease	- Consideration of community health and safety will be implemented based on requirement of international guidelines such as EHS Guidelines by IFC. - Not compromise availability of water for personal hygiene, agriculture, and other community needs - Ensuring traffic safety to community on transportation of fuel and other materials -Measures of infectious disease will be implemented as follows; Plan for prevention of infectious disease from spreading Training to workers Communication with local resident including lecture
Emergency Risk	Flood risks	- Proper elevation level will be set to avoid flood risks such as heavy rain, typhoon, high tide water, and tsunami.
	Risks for fire	- Fire protection facilities such as fire hydrants will be installed.

6. ENVIRONMENTAL MONITORING PLAN (EMOP)

6.1 EMOP before Construction Phase and during Construction Phase

Environmental monitoring plan including monitoring items, location, frequency and responsible organization at before-construction phase and construction phase are shown in Table 6.1 and Table 6.2. The contractor is in charge of implementation of monitoring and report preparation based on monitoring results. The contractor shall also submit monitoring report to the Project Proponent once a month. The cost for implementation of environmental monitoring shall be expensed by the contractor

Table 6.1 Monitoring Plan (Before Construction Phase)

Category	Item	Location	Frequency	Responsible Organizations
Common	- Monitoring of designing for mitigation measures for air pollution, water quality, noise, land elevation for prevention of flood, greening - Monitoring of planning for mitigation measures in construction phase	Project site	Once	Contractor

Table 6.2 Monitoring Plan (Construction Phase)

Category	Item	Location	Frequency	Responsible Organizations
Common	- Monitoring of mitigation measures shown in Table 4.1-4.5	-	Once/month	Contractor
Ambient Air Quality	- Monitoring of status of spraying water to prevent dust in dry season by visual inspection	Construction site and its surrounding area	Everyday	Contractor
Emission Gas	- NOx	Construction site (each emission point)	1 week (test operation)	Contractor
Water Quality	- Maintenance record of septic tank - BOD, COD, Oil and grease, pH Value, Total coliform bacteria, Total SS (in case of discharging wastewater) - Record of collection of wastewater (in case keeping wastewater in the tank)	Wastewater treatment facility/ outlet of septic tank (1 point)	Once/2 month	Contractor
	- As, Cd, Total Cr, Cu, Fe, Pb, Hg, Oil & Grease, pH, Temperature Increase, Total residual chlorine, Total SS, Zn (in case of using demineralization at test operation case)	Outlet of wastewater discharge from demineralization plant (1 point)	4 times/day (test operation)	Contractor
Waste	- Amount of solid waste	Construction site	Once/month	Contractor

Category	Item	Location	Frequency	Responsible Organizations
	- Recording of management of construction waste - Recoding of hazardous and chemical substance management			
Noise and Vibration	- Noise level	Record of advance notice to residence for implementation of construction work at night time	Monthly	Contractor
		1m from the thermal plant (each unit)	5 times/day (test operation)	Contractor
		Nearest residence around project site (1 point)	24 hrs (test operation)	Contractor
Occupational health and safety	- Status of condition of occupational safety and health	Construction site	Once/month	Contractor
Community health and safety	- Status of condition of community safety and health	Construction site and surrounding area	As occasion arises	Contractor

6.2 EMOP during Operation Phase

Environmental monitoring plan including monitoring items, location, frequency and responsible organization during operation phase are shown in Table 6.3. The Project Proponent is in charge of implementation of monitoring and report preparation based on monitoring results. The Project Proponent shall also submit monitoring report to Ministry of Natural Resources and Environmental Conservation (MONREC) and Thilawa SEZ Management Committee (TSMC) every six month. The cost for implementation of environmental monitoring shall be expensed by the Project Proponent

Table 6.3 Monitoring Plan (Operation Phase)

Category	Item	Location	Frequency	Responsible Organizations
Common	- Monitoring of mitigation measures shown in Table 5.1	-	Once/month	Project Proponent
Emission Gas	- NOx	Project site (each emission point)	2 times /year	Project Proponent
Water Quality	- Maintenance record of septic tank	Wastewater treatment facility	Monthly	Project Proponent
	- BOD, COD, Oil and grease, pH Value, Total coliform bacteria, Total SS	outlet of septic tank (1 point)	2 times /year	Project Proponent
	- As, Cd, Total Cr, Cu, Fe, Pb, Hg, Oil & Grease, pH, Temperature Increase, Total residual chlorine, Total SS, Zn (in case of using demineralization)	Outlet of wastewater discharge from demineralization plant (1 point)	2 times /year	Project Proponent

Category	Item	Location	Frequency	Responsible Organizations
Waste	- Amount of solid waste - Recording of management of construction waste - Recoding of hazardous and chemical substance management	Project site	Once/month	Project Proponent
Noise and Vibration	- Noise level	1m from the thermal plant (each unit)	5 times/day in every six month	Project Proponent
		Nearest residence around project site (1 point)	24 hrs in every six month	Project Proponent
Occupational health and safety	- Status of condition of occupational safety and health	Project site	Once/month	Project Proponent
Community health and safety	- Status of condition of community safety and health	Project site and surrounding area	As occasion arises	Project Proponent
Accident	- Record of accident	Project site	As occasion arises	Project Proponent
Flood risk	- Record of flood and its response	Project site	As occasion arises	Project Proponent
Risk for fire	- Record of fire and its response	Project site	As occasion arises	Project Proponent

Appendix-3

Documents of Stakeholder Meeting

The Republic of the Union of Myanmar
Ministry of Electricity and Energy
Electric Power Generation Enterprise
Department of Thermal Power Plant

Letter No. 944 / ThaLaWa GT / 2017

Date. 2017/ November / 6

To

Subject : Invitation of Stakeholder Meeting for the feasibility study of proposal for improvement of Thilawa Power Plant (50 MW)

Reference: Chief Engineer, Department of Thermal Power Plant, Letter No. 3523/PaSaAh (Thilawa)/2017, 24.10.2017

With regard to the above-mentioned subject, Nippon Koei Co., Ltd as a consultant organization is performing the feasible study for repowering of Thilawa Power Plant (50 MW) in Thilawa Area which is one of the Infrastructure Development Projects in Thilawa Area (Zone A) in cooperation with Electric Power Generation Enterprise (EPGE) of the Ministry of Electricity and Energy.

Thus, stakeholder meeting will conduct for the project of improvement of power supply system at feasibility study stage according to the Ministry of Natural Resources and Environmental Conservation and Japan International Cooperation Agency (JICA) guidelines.

We would like to invite you with invitation letter to attend the meeting that Nippon Koei Co., Ltd will conduct at 15 November 2017, (9:00 AM to 10:30 AM), Housing Department Office, at the corner of Thilawa Road and Thanlyin-Kyauktan Road, Thanlyin Township.

Agenda of Stakeholder Meeting

No.	Subject	Date of PCM	Place
1.	Feasible Study for improvement of electricity supply in Thilawa Area	15th November, 2017 (Wednesday) (9:00AM to 10:30 AM)	Housing Department Office, at the corner of Thilawa Road and Thanlyin-Kyauktan Road, Thanlyin Township

Sincerely,

Power Station Manager

(Kyaw Tun Aung, Chief Engineer)

(Thilawa Gas Turbine)

Cc: Director General, Electric Power Generation Enterprise, Naypyitaw
Chief Engineer, Thermal Power Department, Electric Power Generation Enterprise, Naypyitaw

Distribution (List of Invitees)

General Administration Department Office, Yangon Southren District
General Administration Department Office, Thanlyin Township
General Administration Department Office, Kyauktan Township
Yangon Electricity Supply Corporation (YESC), Yangon Southren District
Yangon Electricity Supply Corporation (YESC), Thanlyin Township
Yangon Electricity Supply Corporation (YESC), Kyauktan Township
Environmental Conservation Department, Yangon
Department of Agriculture Land Management and Statistics, Ministry of Agricultural, Livestock and irrigation, Thanlyin Township
Department of Agriculture Land Management and Statistics, Ministry of Agricultural, Livestock and irrigation, Kyauktan Township
Thanlyin Township Development Committee
Kyauktan Township Development Committee
Road Department, Ministry of Construction (MOC), Yangon Southern District
Road Department, Ministry of Construction (MOC), Thanlyin Township
Road Department, Ministry of Construction (MOC), Kyauktan Township
Shwe Pyi Thar Yar Ward Office, Kyauktan Township
Aye Mya Thida Ward Office, Kyauktan Township
Thidar Myaing Ward Office, Kyauktan Township
Shwe Pyauk Village Tract Office, Kyauktan Township
Ah Lun Soke Village Tract Office, Thanlyin Township
Ah Nouk Pine Ward Office, Kyauktan Township
San Chane Mi Ward Office, Kyauktan Township
Ah Lal pine Ward Office, Kyauktan Township
Sin Kan Ward Office, Kyauktan Township
Ah Shae Pine Ward Office, Kyauktan Township
Thilawa SEZ Management Committee
Myanmar Japan Thilawa Development Co., Ltd

ပြည်ထောင်စုသမ္မတမြန်မာနိုင်ငံတော်
လျှပ်စစ်နှင့်စွမ်းအင်ဝန်ကြီးဌာန
လျှပ်စစ်ဓာတ်အားထုတ်လုပ်ရေးလုပ်ငန်း
သီလဝါသဘာဝဓာတ်ငွေ့သုံးဓာတ်အားပေးစက်ရုံ

သို့
စီမံကိန်းမန်နေဂျာ (၁)
ဓာတ်အားပို့လွှတ်ရေးစီမံကိန်း (တောင်ပိုင်း)၊ လျှပ်စစ်ဓာတ်အားပို့လွှတ်ရေး နှင့်
ကွပ်ကဲရေးဦးစီးဌာန၊ ရန်ကုန်တောင်ပိုင်းခရိုင်

စာအမှတ်၊ ၉၄၅ / သလဝ(GT) / ၂၀၁၇
ရက်စွဲ၊ ၂၀၁၇ ခုနှစ်၊ နိုဝင်ဘာလ (၆) ရက်

အကြောင်းအရာ။ သီလဝါလျှပ်စစ်ဓာတ်အားပေးစက်ရုံ (၅၀ မီဂါဝပ်)အား ထပ်မံလျှပ်စစ်ဓာတ်အား တိုးမြှင့်ပေးဝေရေး နည်းလမ်းများအား လေ့လာဆန်းစစ်ခြင်း(Feasibility Study) လုပ်ငန်းများဆောင်ရွက်ရန်အတွက် အထောက်အကူပြု အဖွဲ့အစည်းများ နှင့် သက်ဆိုင်ရာ ဝန်ကြီးဌာနများ ပါဝင်မည့် Stakeholder Meeting အား ဖိတ်ကြားခြင်း။

ရည်ညွှန်းချက်။ အင်ဂျင်နီယာချုပ် အပူစွမ်းအင်သုံးစက်ရုံများဌာန၏ (၂၄.၁၀.၂၀၁၇) ရက်စွဲပါ စာအမှတ် ၃၅၂၃/ ပစအ(သီလဝါ) /၂၀၁၇

၁။ အထက်အကြောင်းအရာပါ ကိစ္စနှင့်ပတ်သက်၍ အကြံပေးကုမ္ပဏီဖြစ်သော Nippon Koei Co.,Ltd အနေဖြင့် လျှပ်စစ်နှင့်စွမ်းအင်ဝန်ကြီးဌာန ၊ လျှပ်စစ်ဓာတ်အားထုတ်လုပ်ရေးလုပ်ငန်းနှင့် ပူးပေါင်း၍ သီလဝါအထူး စီးပွားရေးဇုန် (အပိုင်း က)၏အခြေခံအဆောက်အအုံများ ဖွံ့ဖြိုးတိုးတက်ရေးတွင် တစ်ခုအပါအဝင်ဖြစ်သော သီလဝါ ဧရိယာအတွင်းရှိ လျှပ်စစ်ဓာတ်အား ဖွံ့ဖြိုးရေး စီမံကိန်း၏ လျှပ်စစ်ဓာတ်အားပေးစက်ရုံ (၅၀ မီဂါဝပ်)အား ထပ်မံလျှပ်စစ်ဓာတ်အား တိုးမြှင့်ထုတ်လုပ်ရေး စီမံကိန်းအကောင်အထည်ဖော်မှု နည်းလမ်းများအားလေ့လာ ဆောင်ရွက်လျက်ရှိပါသည်။

၂။ သို့ဖြစ်ပါ၍ သယံဇာတနှင့်သဘာဝပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဝန်ကြီးဌာန နှင့် ဂျပန် အပြည်ပြည်ဆိုင်ရာ ပူးပေါင်းဆောင်ရွက်ရေး အေဂျင်စီ (JICA) မှထုတ်ပြန်ထားသော လမ်းညွှန်ချက်နှင့်အညီ ယခု လျှပ်စစ်ဓာတ်အားတိုးမြှင့်ထုတ်လုပ်ရေး စီမံကိန်း အကောင်အထည်ဖော်မှု ဖြစ်နိုင်ခြေနည်းလမ်းများအား လေ့လာဆန်းစစ်ခြင်း (Feasibility Study)

အဆင့်တွင် အကျိုးဆက်စပ်သူများ ပူးပေါင်းပါဝင်သော အစည်းအဝေးပွဲ (Stakeholder Meeting) အား ကျင်းပပြုလုပ်မည် ဖြစ်ပါသည်။

၃။ အထက်ပါအစည်းအဝေးအား အကြံပေးကုမ္ပဏီဖြစ်သော Nippon Koei Co.,Ltd မှ တာဝန်ယူ ဆောင်ရွက်မည်ဖြစ်ပါ၍ ၂၀၁၇ ခုနှစ်၊ နိုဝင်ဘာလ၊ ၁၅ ရက်နေ့ (နံနက် ၉ နာရီ မှ ၁၀ နာရီ ထိ) အချိန်၊ မြေယာရုံးခွဲ (၂)၊ အိုးအိမ်ဦးစီးဌာန၊ သန်လျင်မြို့နယ်၊ (သန်လျင်-ကျောက်တန်းလမ်း နှင့် ဒဂုံ-သီလဝါလမ်းဆုံ)တွင် အကျိုးဆက်စပ်သူများပူးပေါင်းပါဝင်သော အစည်းအဝေးပွဲ (Stakeholder Meeting)အား ကြွရောက်နိုင်ပါရန် ဖိတ်ကြားလာပါသဖြင့် ဖိတ်စာနှင့်တကွ ပေးပို့ဖိတ်ကြားအပ်ပါသည်။

အစည်းအဝေး ကျင်းပပြုလုပ်မည့် အစီအစဉ်

စဉ်	အစည်းအဝေး အကြောင်းအရာ	ကျင်းပမည့် နေ့ရက်၊အချိန်	ကျင်းပမည့် နေရာ
၁။	သီလဝါ ဧရိယာအတွင်း လျှပ်စစ်ဓာတ်အား ဖွံ့ဖြိုး တိုးတက်ရေး အတွက် ကနဦးလေ့လာရေး လုပ်ငန်းများ ဆောင်ရွက်ခြင်း	၂၀၁၇ ခုနှစ်၊ နိုဝင်ဘာလ (၁၅) ရက် (ဗုဒ္ဓဟူးနေ့) နံနက် ၉ နာရီ မှ ၁၀ နာရီ ထိ	မြေယာရုံးခွဲ (၂)၊ အိုးအိမ်ဦးစီးဌာန၊ သန်လျင်မြို့နယ်၊ (သန်လျင်-ကျောက်တန်းလမ်း နှင့် ဒဂုံ - သီလဝါ လမ်းဆုံ)

6-11-2017

စက်ရုံမှူး

(ကျော်ထွန်းအောင်၊ အင်ဂျင်နီယာမှူးကြီး)

(သီလဝါ သဘာဝဓာတ်ငွေ့သုံးဓာတ်အားပေးစက်ရုံ)

မိတ္တူကို -

ဦးဆောင်ညွှန်ကြားရေးမှူး၊ လျှပ်စစ်ဓာတ်အားထုတ်လုပ်ရေးလုပ်ငန်း၊ နေပြည်တော်။

အင်ဂျင်နီယာချုပ်၊အပူစွမ်းအင်သုံးစက်ရုံများဌာန၊ လျှပ်စစ်ဓာတ်အားထုတ်လုပ်ရေးလုပ်ငန်း၊ နေပြည်တော်။

ဖြန့်ဝေခြင်း -

အထွေထွေအုပ်ချုပ်ရေးဦးစီးဌာန၊ ရန်ကုန်တောင်ပိုင်းခရိုင်။
အထွေထွေအုပ်ချုပ်ရေးဦးစီးဌာန၊ သန်လျင်မြို့နယ်။
အထွေထွေအုပ်ချုပ်ရေးဦးစီးဌာန၊ ကျောက်တန်းမြို့နယ်။
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သီလဝါအထူးစီးပွားရေးဇုန် စီမံခန့်ခွဲမှုကော်မတီ။
Myanmar Japan Thilawa Development Co.,Ltd

Outline of the Repowering Project of Thilawa Power Station

November 2017
Japan International Cooperation Agency
Nippon Koei Co., Ltd.

Table of Contents

1-1. Current Issue on Power System in Myanmar

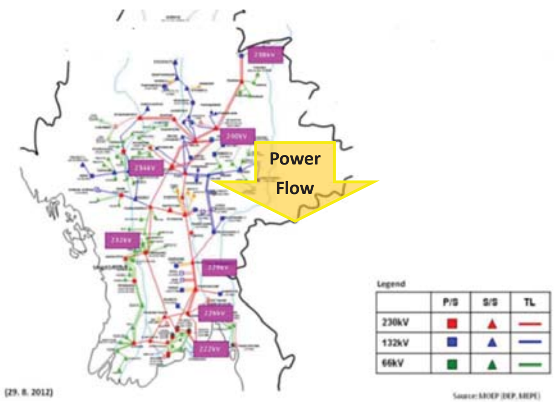
~ Total power System in Myanmar~

- Insufficient Power Supply: Caused by Increasing Demand
- Major Power Source: Large Hydro in Northern Part of Myanmar
- Major Consumer: Southern Part of Myanmar (e.g. Yangon)

- Power Flow: North to South

- **Stable power generation in South (by thermal) is needed.**

- *Priority of Generation*
  1. *Hydropower Plants*
  2. *Thermal with Good Efficiency (e.g. Combined Cycle)*
  3. *Aged Thermal Plants*



1-2. Current Issue on Power System in Myanmar

~ Location of the existing Thilawa Power Station~

Relevant Organizations : Ministry of Electricity and Energy,
Thilawa SEZ Management Committee

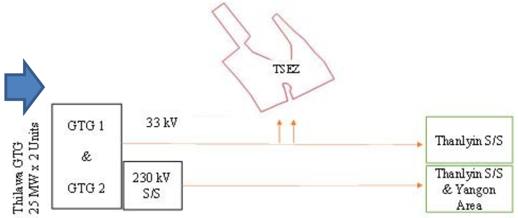
Presentation Material

1-3. Current Issue on Power System in Myanmar

~ Power Supply in Thilawa Area~

Thilawa Power Plant :

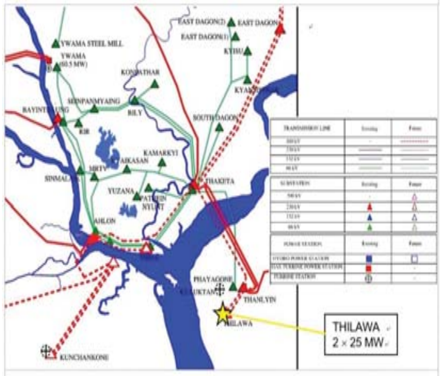
25 MW x 2 Units = 50 MW



- In Thilawa SEZ, two units of GTG plant with rated capacity of 25 MW each has been installed for power supply to Thilawa SEZ and Yangon through JICA Loan.
- In the future, demand forecast will excess the capacity and enhancement of power supply to the SEZ will be required for stable operation in the area.
- Considering the low load at the SEZ during nights, generated power will be supplied to the national grid towards Yangon.

1-4. Current Issue on Power System in Myanmar

~ Vicinity power System in Thilawa Power Station~



National Grid Plan around Yangon in 2016-2020 (as of 2015)

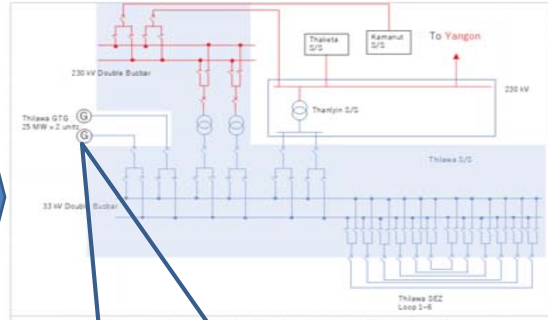


Figure2 Overview of Power System Diagram nearby Thilawa SEZ

Figure1 Overview of Distribution Line near Thilwa SEZ Today

Photo1 Thilawa GTG Plant　Photo2 Distribution Line in Thilawa SEZ

- **Study Focus :**

(i) Stability of National Grid with Existing 50 MW

(ii) Enhanced Capacity to GTGs

(iii) Enhancement of Capacity with additional facility

(iv) Addition of New Feeders

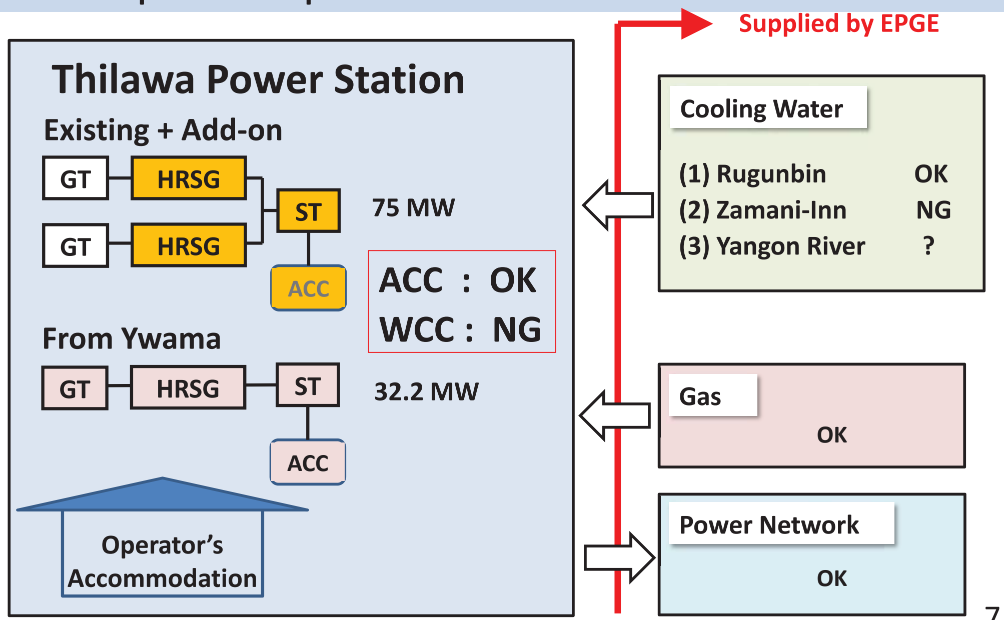
2-1. Outline of the Repowering Project

~Main Consideration for Selection Options~

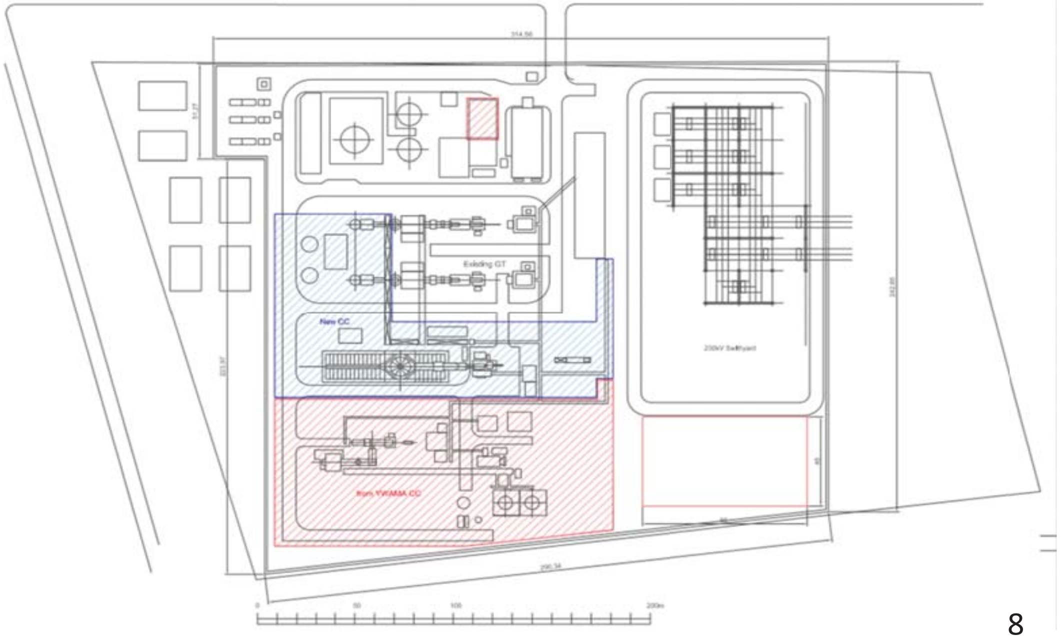
- Development plan for new power source, which is not included in the latest Master Plan, can also play an important role to alleviate the gap between demand and supply.
- For next ten years, the *gas production* looking at indigenous in Myanmar seems to drop. Turning to awareness of environment in the public of Myanmar.
- It is preferable to enhance generation capacity with add-on combined cycle system to the existing GTG plant rather than installation of new power plant.
- So, enhancement of the existing Thilawa GTG power plant is being considered through **adaptation of combined cycle system**.
- The alternatives for upgrading of power supply system in Thilawa Area are proposed from **the aspects of electrical and thermal techniques with economic and financial, and environmental considerations**. The best available plan is selected.

2-2. Outline of the Repowering Project

~Input and Output for Power Station~

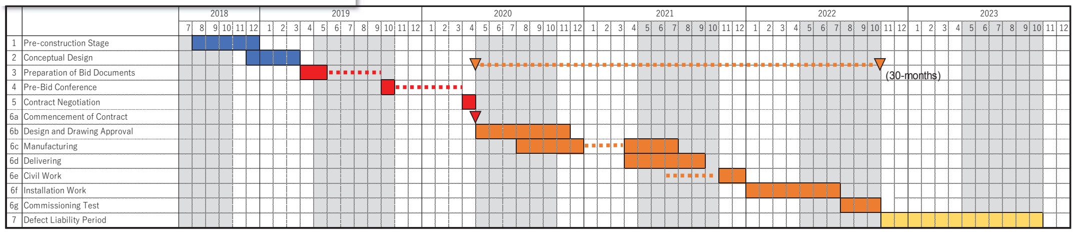


2-3. Outline of the Repowering Project
~ Layout of Thilawa Power Station with New Units ~



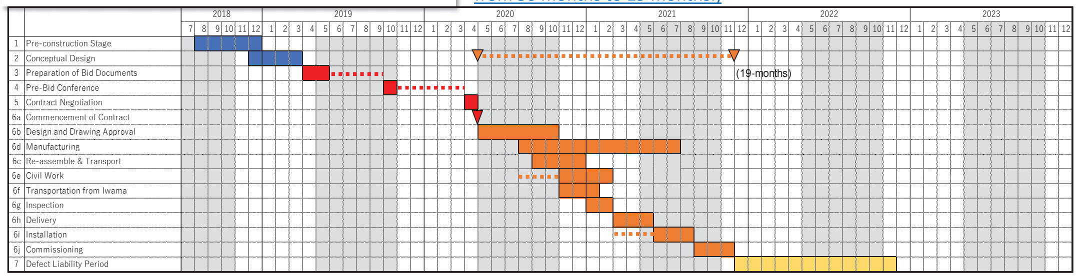
2-4. Outline of the Repowering Project
~ Project Implementation Schedule ~

Schedule for Thilawa Add-on



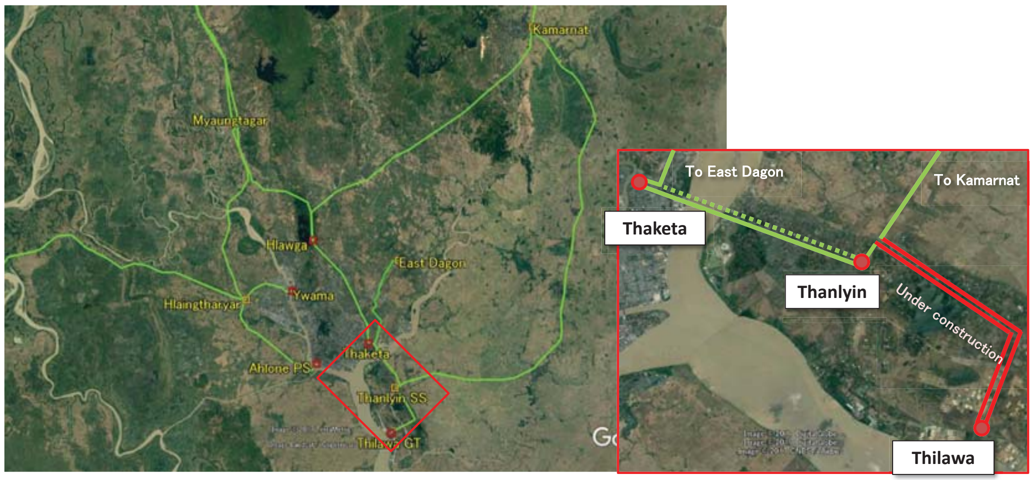
The schedule will be shorter than the one of Add-on component because of shorter manufacturing duration. (Construction period will be reduced from 30 months to 19 months.)

Schedule for Relocation from Ywama



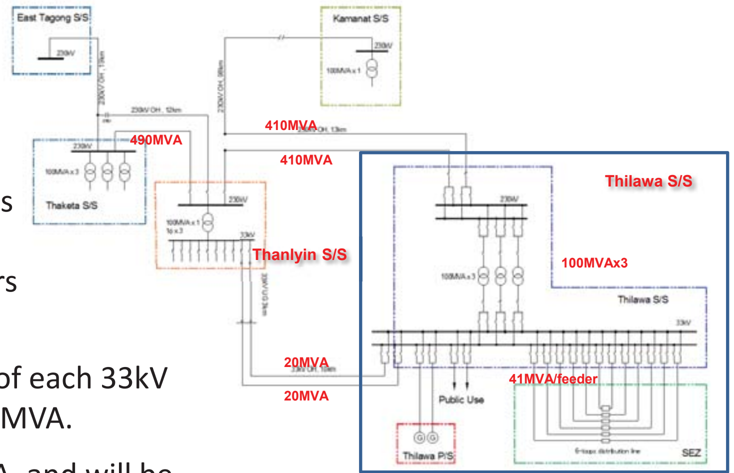
3-1. Transmission Lines and Substations
~ 230kV Transmission Line from Thilawa P/S ~

1. 230kV Thilawa – Thanlyin, Thilawa – Kamarnat is under-construction.
2. Thilawa P/S will be connected to 230kV national power grid.



3-2. Transmission Lines and Substations
~ Capacity of Transmission Lines & Substations ~

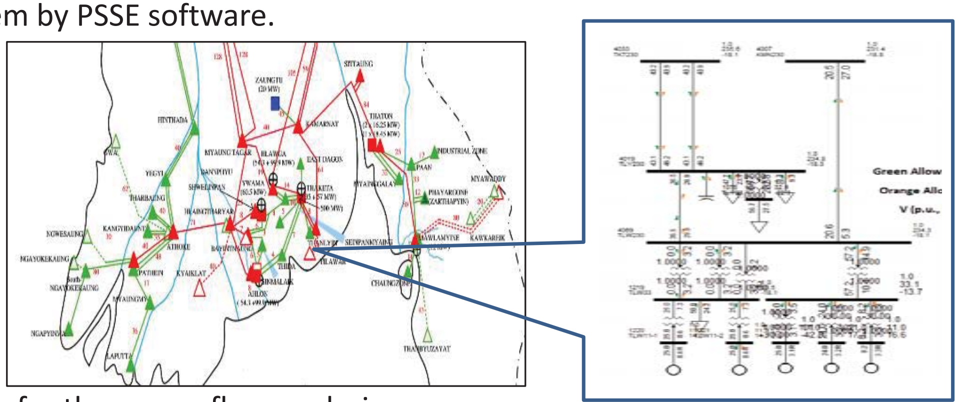
1. Thilawa Substation is under-construction, and has transformers of 100MVA x 3.
2. Maximum capacity of each 33kV feeder is 1,250A, 41MVA.
3. 33kV bus has 2,500A, and will be upgraded to 5,000A
4. Transmission line has enough capacity of 410MW (75deg)



4-1. Power System Analysis

~ Criteria for the power flow analysis ~

For repowering of Thilawa P/S , System analysis was conducted in the vicinity power system of Thilawa P/S including Yangon area to verify the system problem by PSSE software.



Criteria for the power flow analysis

- Sufficient capacity of main components under normal or disturbance situations (N-1 rule)
- Sufficient capacity of reactive compensation equipment to ensure voltage limits
- Sufficient capacity of circuit breakers to ensure the remove three-phase short circuit faults

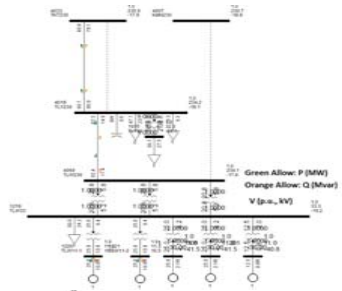
4-2. Power System Analysis

~ Result of Power System Analysis ~

Lj Evaluation of Power Flow

Judging from the simulation result,

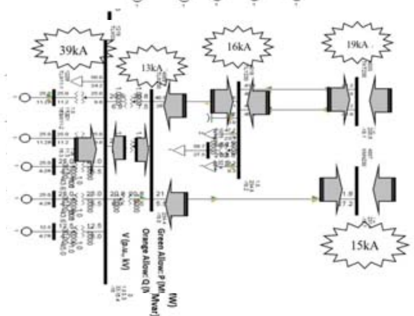
- System is operated in stable within the suitable voltage level and power flow under abnormal condition
- Additional repowering power is 57.2MW. On the other hand, 230kV T/L has large sending capacity of 410~490MW



Lj Evaluation of Short Circuit Capacity

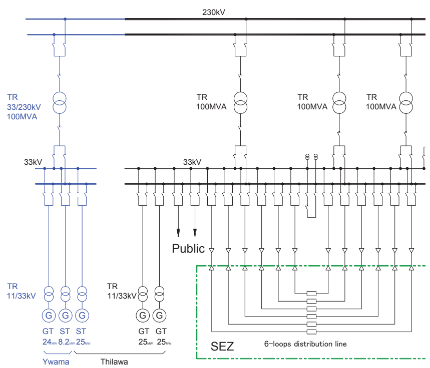
Judging from the simulation result,

- There seems to be no severe problem because total short circuit value of 33kV bus is under 40kA
- Regarding the 230kV Bus of Each S/S, the short circuit capacity seems to be under 40 kA as well

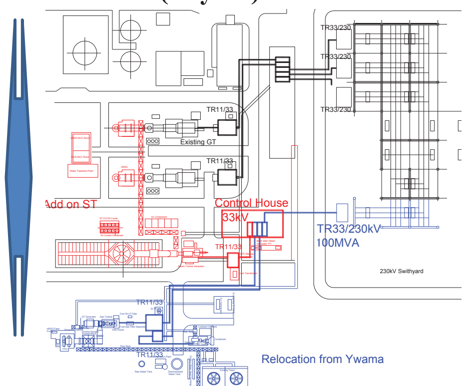


5. Recommendation TG Connection Method

(Single Line Diagram)



(Layout)



* The additional TGs should be connected to 230kV Bus through the Step up transformer respectively
* The existing 33/230kV transformer of 3 units could be utilized to meet increasing demand of Thilaea SEZ
* There are no problem regarding to this configuration of TG connection form the power flow & Short circuit level view point.
* There is no problem from the view point of Layout as well

6-1. Environmental and Social Consideration

~ Current Environmental Management ~

@@@ Scoping Report for existing power plant (50MW) has been reviewed and received comments from Environmental Conservation Department @@@

@@@ Draft Environmental Impact Assessment Report for existing power plant (50MW) has been prepared@@@

@@@Environmental Monitoring Plan has been started for gas emission and noise and vibration control@@@

6-2. Environmental and Social Consideration

~ Current Target Values and NEQG's Guidelines for Thermal Power Plant~

Environment Element	Guideline Value	Note
Emission gas	NOx:100mg/Nm3 (49ppm)	For gas turbine project (not less than 50MW) **Current Target Values : 125 mg/Nm3 (61ppm) as per WB Guideline**
Wastewater	As: 0.5mg/L, Cd: 0.1mg/L, Total Cr: 0.5 mg/L, Cu: 0.5mg/L, Fe: 1mg/L, Pb: 0.5mg/L, Hg: 0.005mg/L, Oil & Grease: 10mg/L, pH : 6-9, Temperature Increase: less than 3°C, Total residual chlorine: less than 0.2mg/l, Total suspended solids: 50 mg/L, Zn: 1mg/L	For thermal plant **Current GTG has no industrial wastewater discharge.**
Noise	Residential, institutional, educational [Weekday] 55dB (7 am to 10 pm), 45dB (10 pm-7 am) [Weekend] 55dB (10 am to 10 pm), 45dB (10 pm-10 am) Industrial, commercial 70 dB (all day)	Guideline values are applied to all sectors but criteria for the land use is not clear

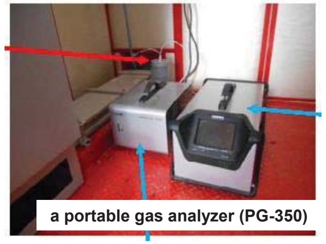
6-3. Environmental and Social Consideration

~ Current Gas Emission Control Measures~

@@@ Water Injection System for each Gas Turbine is installed to control the NOx emission by injecting demineralized water into the combustor through the fuel nozzles to regulate the combustor flame temperature and lower NOx emission. @@@

@@@Currently the water injection system has not been operated yet due to the half load operation of GTGs and lack of water supply (demineralized water) required for the injection system (600 tons/day)@@@

@@@ On the other hand, the emission without water injection is monitored by a portable gas analyzer (PG-350), Product of HORIBA @@@



a portable gas analyzer (PG-350)

CO_2 Fire Fighting System

@@@ The CO_2 Fire Fighting System Room is also installed by connecting copper tube between apparatus and measuring probe @@@

6-4. Environmental and Social Consideration

~ Current Monitoring Results: Gas Emission~

Month/Year	GTG1 NOx (ppm)	GTG2 NOx(ppm)	Operation Condition
August/2016	65.2	62.6	Half of Generation Capacity (25 MW) without water injection system
September/2017	69.0	69.0	Full Generation Capacity (50 MW) without water injection system

The emission gas without water injection were just slightly over the target value of NO_x emission (61 ppm, World Bank Standard) described in the draft EIA report. The NEQG's value for NOx emission is 49 ppm (100 mg/Nm^3) In case of operating of water injection system, it is expected to meet the target value of NEQG. Because the installation of water injection system can reduce up to 25 ppm of NOx as per design values of the system.

6-5. Environmental and Social Consideration

~ Current Monitoring Results: Noise Level~

Results of Noise Measurement near Power Plant

<u>7 monitoring points</u>

DD_1 @1m from gas turbine - 86.1 dB
DD_2 @2m from gas turbine - 86.0 dB
DD_3 @ 4m from gas turbine - 85.3 dB
DD_4 @ 8m from gas turbine – 82.9 dB
DD_5 @23m from gas turbine – 81.0 dB
DD_6 @50m from gas turbine – 73.5 dB
DD_7 @100m from gas turbine – 71.9 dB

85 dB

Results of Noise Measurement at boundary and nearest resident

<u>5 monitoring points</u>

SD_1 - 79.4 dB
SD_2 - 74.8 dB
SD_3 - 73.1 dB
SD_4 - 76.2 dB

Nearest Resident – 59 dB (day time) ; 60 dB (night time)

70 dB

* Apply NEQG Guidelines

6-6. Environmental and Social Consideration

~ Alternatives: Four Options for Improvement of Power System~

	Option 1	Option 2	Option 3	Option 4
Characteristics	Thilawa Add-on CC of existing 2GTs (1ST)	Ywama Relocation NEDO Unit (1GT+1ST)	Ywama Relocation NEDO Unit/CC of (3GTs+1ST)	Op.1 + Op.2
Composition of Plant (GT:G:STG)	2:2:1	2:2 (Existing) 1:1:1	3:3:1	2:2:1 1:1:1
Water Consuption (ton/day)	250 (ACC) 3,340(WCC)	83 (ACC) 1,104 (WCC)	375 (ACC) 5,010 (WCC)	333 (ACC) 4,444 (WCC)
Additional Capacity (MW)	25	32.2	23.2+36.6	25+32.2
Total Capacity (MW)	75 (50+25)	82.2 (50+32.2)	109.8 (50+23.2+36.6)	107.2 (50+25+32.2)
Additional EPC Cost (Mil. USD)	59.5	41.0	less than Option 4	100.5 (59.5+41.0)
FIRR				
EIRR				
Environment	-	Need to Checi Emission of Ywama NEDO unit		
Social	-	If land extension, need to check Income Restoration as per necessity		
Construction Period	24 - 30 months	19 months	-	-

The JICA study team recommends that Option 4 is the best option considering 1) Smooth construction of the Project, 2) Construction timing of Option 1 and Option 2, 3) No significant difference between Option 3 and 4, and 4) Restriction of Gas supply, etc.

6-7. Environmental and Social Consideration

~ Implementation of Option-4 : Water Use~

Reasons : *Water is required for reduction of Nox emission from Gas Turbines!*

& Cooling water is required for Combined Cycle Gas Turbines!

Estimated Water Consumption Amount :

6300 tons/day (Water Cooling System) (or) 1700 tons/day (Air Cooling System)

Possible cooling method to be used *:Air Cooling System*

Selection of Source of Water

Groundwater usage by Tube well

****higher salinity; ground subsidence; decrease in underground water level*

Surface Water Usage

(i) Zamini-Inn

**** Limited of water availability*

(ii) Yangon River

**** higher salinity; effect on heat exchange system; land requirement for piping network*

(iii) Rugunbin Dam

**** large water amount (6300 tons/day) is impossible; but 1700 tons/day is possible*

Possible source *: Rugunbin Dam*

6-7. Environmental and Social Consideration

~ Implementation of Option-4~

Gas Emission

Combined Cycle System in existing GTGs *: Control for gas emission due to water injection system*

Relocation of Ywama GTG and ST*: Need to check the gas emission status*

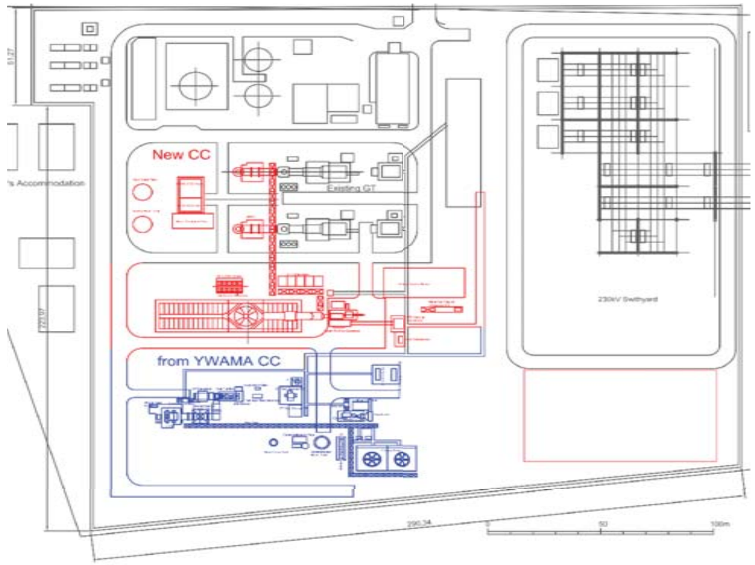
Wastewater

Current *: No wastewater discharge*

Operation of water injection and combine cycle*: Need to check supplied water quality*

6-7. Environmental and Social Consideration

~ Implementation of Option-4 : Social Consideration on Land Use~



6-7. Environmental and Social Consideration

~ Implementation of Option-4: : Social Consideration on Land Use ~

1) Land was compensated in 1998. The figure shows boundary of project site (10 Ha) as well as F50 and E2 which are the current cultivation area.
2) If the expansion land is necessary and there are the residences' cultivating in that area, the TSMC will discuss with crop compensation policy as well as based on Resettlement Work Plan for Thilawa SEZ Zone A Development in Feb 2015.
3) However, as shown the figure, there are no resident and cultivation in the area of proposed expansion.

6-8. Environmental and Social Consideration

~ Stakeholder Meetings~

1) Past Stakeholder Meetings

1) PCM* for 50 MW project (Scoping Stage): Mar 2014

2) PCM* for 50 MW project (Draft EIA Stage): Sep 2014

3) Individual meeting on crop compensation between surrounding households (2 households) and government organizations (TSMC and MOEE): Feb 2015

* PCM: Public Consultation Meeting
* TSMC: Thilawa SEZ Management Committee

2) Current Stakeholder Meeting

For Feasible Study on Improvement of Power Supply in Thilawa Area : 15 November 2017

6-9. Environmental and Social Consideration

~ EIA Study for the Repowering Project~

MONREC-ECD advised to update existing draft EIA report for 50 MW and to apply the review of updated EIA report for the repowering Project.

Expected Schedule of EIA study for the repowering Project

No.	Description of Actions	Expected / Required Time Period	Remark
0	Completion of F/S Report		
1	Preparation for updating draft EIA Report	2 months	
2	Arranging public consultation, disclosure and finalization of EIA Report	2 months	
3	Submission of final EIA Report* and Appraisal	4.5 months	*MOEE's cover letter on request of urgent review shall be required.
4	Approval by NECCCCC*	4 months	* National Environmental Conservation and Climate Change Central Committee * Committee meeting organizes every 4 months

***It may take totally about 12.5 months

Thank
for
Your attention

ကျေးဇူးတင်ပါတယ်

Stakeholder Meeting for The Repowering Project of Thilawa Power Station

Meeting Record

Date and Time	15th November 2017 9:30-11:00	Venue	Housing Department Office, at the Corner of the Thilawa Road and Thanlyin-Kyauktan Road, Thanlyin Township
Meeting organized by	Nippon Koei Co., Ltd (Japan)		
Agenda :	See Attachment-1 for details		
Participants:	Total 28 persons (see Attachment-2 for details) Thilawa SEZ Management Committee (TSMC) : 3, General Administration Department (GAD) :3, Township Development Committee (TDC) :1, Environmental Conservation Department (ECD) :1, Yangon Electricity Supply Corporation (YESC) : 4, Road Department, Ministry of Construction (MOC): 3, Department of Agriculture Land Management and Statistics, Ministry of Agricultural, Livestock and irrigation : 1, Ministry of Electricity and Energy (MOEE): 2, Villages : 3, Companies and others: 7		
Presenters:	Team Leader of JICA Study Team Environmental Expert of JICA Study Team		
Opening Remark:			

Joint Secretary, TSMC gave an opening speech as follows.

(i) Thilawa Special Economic Zone was started to operate in 1st December, 2013 and up to now, total 86 companies from 17 different countries come to invest in Thilawa with the amount of 1.17 billion during the last four years.

(ii) It can be said that Thilawa Special Economic Zone becomes the most successful SEZ in Myanmar and it could also be recognized within ASEAN countries.

(iii) For the development issues, infrastructure development is very important especially in electricity, water supply, road, internet fibers and etc. Among them, getting full capacity of electricity takes the leading role.

(iv) For the starting of Thilawa SEZ, the required electricity was delivered via 33 kV lines from Thanlyin Sub-station and then 50 MW power plant has been constructed.

(v) Now the power plant can produce 25 MW and Ministry of Electricity and Energy is trying to operate fully with 50 MW. Moreover, it is finding the possibilities to upgrade up to double of the current capacity (around 107 MW) in cooperation with JICA.

(vi) In implementing the required processes, environment impacts are considered not to be affected and to be less as much as possible.

(vii) At the present, 38 out of 86 factories are in operation stage and using the half amount of available electricity (25 MW). There are many potentials to expand the TSEZ zone more and more.

(viii) Getting electricity is more important than before as the vehicle manufacturing company, Suzuki Company is also invested in Thilawa SEZ.

(ix) Getting water from Zamani dam is sufficient for the present but required water will be available from La Gun Byin Dam in the near future.

(x) Ministry of Construction is also implementing to construct the road starting from Thanlyin Bridge to Thilawa with ODA Loan and Yangon Regional Government is trying to get the bus lines accessible to Thilawa SEZ Zone.

(xi) At last, he gave special thanks to the relevant Ministries for making the infrastructure development at Thilawa Area in various sectors and concluded the opening speech.

Presentation Topics:

- Introduction project outline of the repowering project of Thilawa power station and Environmental and Social Consideration of the Project were presented by Team Leader and Environmental Expert of JICA Study Team. The following topics are included.

- *Current Issue on Power System in Myanmar*
- *Outline of the Repowering Project*
- *Transmission Lines and Substations*
- *Power System Analysis*
- *Recommendation of TG Connection Method*
- *Environmental and Social Consideration*

The contents of Stakeholder Meeting presentation were briefly introduced as follows,

(i) Power system in Myanmar and two units of GTG plant with rated capacity of 25 MW each has been installed in TSEZ for power supply to Thilawa SEZ and Yangon through JICA Loan. Considering the low load at the SEZ during nights, generated power will be supplied to the national grid towards Yangon.

(ii) The gas production in Myanmar seems to be drop in next ten years. It is preferable to enhance generation capacity with add-on combined cycle system to the existing GTG plant rather than installation of new power plant. The existing Thilawa GTG power plant is being considered through adaptation of combined cycle system.

(iii) The alternatives for upgrading of power supply system in Thilawa Area are proposed from the aspects of electrical and thermal techniques with economic and financial, and environmental considerations. The best available plan is selected.

(iv) Existing two units of GTG plant with 25 MW enhanced through installation HRSG (heat recovery steam generator) and ST (steam turbine) which generated power 75 MW and relocation of GTG unit from Ywama power station which generated power 32.2 MW.

(v) As for social considerations, land acquisition and crop compensations may be not necessary because land for the expansion could be secured within the area of existing property of Thilawa power plant.

(vi) Project implementation period will be 30 months and 230 kV Thilawa-Thanlyin, Thilawa-Kamarnat is under-construction and it will be connected with Thilawa power station. The existing 33/230kV transformer of 3 units could be utilized to meet increasing demand of Thilawa SEZ.

(vii) Scoping Report for existing power plant (50 MW) has been reviewed by Environmental Conservation Department and comments were received. Draft EIA report has been prepared and Environmental Monitoring Plans including gas emissions, noise and vibration control works are implementing at the present.

(viii) When the factory was started to operate, EIA procedures and guidelines were not published. Hence, NEQG guidelines values are not included and referenced in the scoping report and draft EIA report of the factory. Only guidelines from world bank has been taken as reference for the emission values especially for NOx Emission Values. Currently, there is no wastewater extracted from the factory.

(ix) At the present, NEQG guideline has been released and the factory will follow NEQG Guidelines in the future.

(x) Water injecting system is installed at the factory to reduce emissions but due to the facts that the factory is operating with half capacity and water required for water injection system could not be available at this time, that system is not operating at the present. However, portable gas analyzers have been using to monitor the emissions from the factory. CO_2 Fire Fighting System was also installed to prevent the causes of fire accidents.

(xi) Measured emissions results of NO_x in 2016 and 2017 are a little bit more than the World Bank's Guideline Values as the water injection system could not be used at the moment. When water injection system can operate, it can reduce up to 25 ppm of NO_x as per design of water injection system and it will meet the NEQG Guideline Values requirements (49 ppm).

(xii) Noise levels were also measured at 7 monitoring points within 100 m from gas turbines in 2017 and it is found that the noise levels nearer the gas turbine are a little bit higher than the IFC guideline values for occupation health and safety. This should be considered for occupational health and safety issues. Noise levels at four corners of the factory and at the nearest residence are also measured. For the residences, the noise levels at day and night meet the NEQG Guideline values for industrial zone area. Mitigation measures for noise levels need to be considered deeply while preparing the update of EIA report.

(xiii) Before implementing the project, four alternative options have been considered and the best available option was selected.

(xiv) From the view of environmental and social considerations, there are some issues for it and the first priority is water usage. In the power station, water is required for two reasons; to reduce NO_x emissions from Gas Turbines and cooling water for Combined Cycle Gas Turbines. The amount of water is estimated to be 6300 tons per day when using water cooling system and 1700 tons per day for air cooling system. Therefore, air cooling system is suggested from the environmental point of view.

(xv) Ground water from tube wells are strictly prohibited due to the possibility of cause of ground subsidence, decrease in groundwater level and salinity property of ground water. Surface water will be able to get from La Gun Byin Dam for the amount of 1,700 tons per day.

(xvi) For Combined Cycle System, water injection system will be able to control fully when operating it. Gas Emission Status for the relocation of gas turbines from Ywama need to be checked and mitigation measures need to be considered at EIA report preparation stage. There is no wastewater disposal from the factory at this moment but supply water for water injection and combine cycle need to be checked accordingly when the operation is started.

(xvii) The expansion of the project will be in the compound of existing factory and there will not be any impacts for land use as the factory land had been occupied and gave compensations in 1988.

(xviii) As the requirements for EIA, consultation meetings are needed to be arranged and it had been conducted in March, 2014, September, 2014, February, 2015 and this time.

(xix) Draft EIA report had been prepared for this project when it started construction. For the expansion of the project at the present, MONREC-ECD advised to update the existing draft EIA report.

(xx) Time required for EIA report preparation would take about 12 and half months.

Questions and Answers :

- ❖ Deputy General Manager, Yangon Electricity Supply Corporation (YESC), Yangon Southern District

Question-1 Is there any possible effect on electricity supply and generation in using Air cooling system instead of Water cooling system in dry season?

Answer-1 It may slightly effect on the power generation capacity. More detail study about Air cooling type of combined cycle system will be carried out to evaluate the effect of using air cooling type on the power generation during dry season (Team Leader of JICA Study Team)

- ❖ Joint Secretary-1, Thilawa SEZ Management Committee (TSMC)

Suggestion-1 Water supply from La Gun Byin Dam will be available in the end of 2018 and operation cost will be higher than usual; i.e. 1 gallon = 4 kyats. Therefore, it is suggested to consider on the operation cost of water supply as it is more expensive than Zarmani Dam. As compensation phase is completed in 1998, it was suggested to put more concentration on the Technical and Environmental Issues rather than land issue. Also suggested that currently the environmental measures are conducted during operation stage and it is expected that after expansion of the factory, it would be under compliance with the guidelines and standard values.

Answer-1 JICA study team considered about water usage and cost for maintenances in the financial and economic study for repowering of Thilawa Power Plant Project. It will be more cost effective to use water than construction of new gas turbine. (Team Leader of JICA Study Team)

- Assistant Director, OSSC

Suggestion-2 This facts and data including in this presentation is too general. It would be better to provide with more detail assessment for environmental impacts. In order to able to consider of Environmental Issues of the project, the copy of EIA is requested to be sent to OSSC.

Answer-2 As it is the feasibility stage of the project, the detail assessment information is not included. We will provide with detail study and information of the project in EIA study stage. The copy of EIA report will be sent to OSSC when the Draft report is summited to Naypyitaw ECD. (Environmental Expert of JICA Study Team)

Photos of Stakeholder Meeting :	See Attachment-3 for details

Attachment-1

Meeting Agenda

Time	Contents	Organization in Charge
09:00-09:30	Registration	-
09:30-09:45	Opening Remark	Joint Secretary, Thilawa SEZ Management Committee
09:45-10:15	Outline of the Project	Team Leader of JICA Study Team
10:15-10:50	Environmental and Social Consideration of the Project	Environmental Expert of JICA Study Team
10:50-11:00	Questions and Answers	Participants

Attachment-2

Registration Record

No.	Position	Department
1.	Deputy Staff Officer	General Administration Department (GAD), Thanlyin Township
2.	Branch Clerk	General Administration Department (GAD), Kyauktan Township
3.	Deputy General Manager	Yangon Electricity Supply Corporation (YESC), Yangon Southern District
4.	Manager	Yangon Electricity Supply Corporation (YESC), Thanlyin Township
5.	Assistant Engineer	Yangon Electricity Supply Corporation (YESC), Kyauktan Township
6.	Assistant Director	Environmental Conservation Department (ECD), Yangon
7.	Deputy Staff Officer	Thanlyin Township Development Committee
8.	Assistant Director	Road Department, Ministry of Construction (MOC), Yangon Southern District
9.	Engineer	Road Department, Ministry of Construction (MOC), Thanlyin Township
10.	Deputy Staff Officer	Department of Agriculture Land Management and Statistics, Ministry of Agricultural, Livestock and irrigation, Kyauktan Township
11.	Staff Officer	Ministry of Construction (MOC), Thanlyin Township
12.	Ward Administrator	Shwe Pyi Thar Yar Ward, Kyauktan Township
13.	Ward Administrator	Aye Mya Thidar Ward, Kyauktan Township
14.	Representative	Thidar Myaing Ward, Kyauktan Township
15.	Assistant Director	Environmental Conservation Department, (ECD), One Stop Service Committee (OSSC), Thilawa SEZ Management Committee (TSMC)
16.	Assistant Manager	Myanmar Japan Thilawa Development Co., Ltd.
17.	Chemical Engineer	Myanmar Japan Thilawa Development Co., Ltd.
18.	Joint Secretary-1	Thilawa SEZ Management Committee (TSMC)
19.	Public Affairs Coordinators	Thilawa SEZ Management Committee (TSMC)
20.	Junior Clerk	General Administration Department (GAD)
21.	JICA Study Team	Nippon Koei Co., Ltd.
22.	Site Electrical Engineer	Yangon Electricity Supply Committee (YESC)
23.	JICA Study Team (Environment)	Nippon Koei Co., Ltd.
24.	Factory Engineer	Ministry of Electricity and Energy (MOEE)
25.	Chief Engineer	Ministry of Electricity and Energy (MOEE)
26.	Junior Environmental Expert	Myanmar Koei International
27.	Junior Environmental Expert	Myanmar Koei International
28.	Junior Environmental Expert	Myanmar Koei International

Attachment-3

	
Registration	Project Outlines Presentation by JICA Study Team
	
Presentation of Environmental and Social Consideration of Project by JICA Study Team	Suggestion and Discussion among Participants

End of Document

Appendix-4

Methodology of Air Quality Simulation

Appendix 4 Methodology of Air Quality Simulation Model

1 Prediction Item

The items to be predicted are shown below:

- Impacts on air quality caused by operation of gas turbines

2 Prediction Area

The area where the impacts are to be predicted is set in and around the proposed Project site.

3 Prediction Period

The prediction period in the operation stage was set as the duration of operating gas turbines.

4 Prediction Method

The impacts on air quality were predicted using the following methods:

- To estimate the pollutant concentration emitted by operation of gas turbines by using a simulation model, and to assess its impacts in and around the proposed Project site.

The methodology of the impact prediction in the operation stage is described below:

(1) Prediction conditions

1) Cases of Prediction and its Conditions of Emission Gas

The following three cases for the numerical simulation are set to assess cumulative impact of NOx emissions in the upgrading capacity of power supply. The conditions of each case are summarized in Table 1.

Case 0: Existing Condition (50 MW gas turbine without water injection system of existing Thilawa Power)

Case 1: Future Condition 1 (107 MW combined cycles without water injection system of existing Thilawa Power and Ywama gas turbine)

Case 2: Future Condition 2 (107 MW combined cycles with water injection system of existing Thilawa Power and combined cycle without water injection system of Ywama gas turbine)

Table 1: Conditions of Air Quality Simulation Model

Item	Unit	Case 0	Case 2	Case 3	Note
Capacity of electric supply	MW	50	107	107	
Water injection system to the existing power plant in Thilawa	-	Not applicable	Not Applicable	Applicable	The additional gas turbine from the existing Ywama power plant does not have water injection system.
Volume of exhaust gas (dry bases)	Nm3/h	252,333	252,333 (Thilawa) 246,323 (Ywama)	251,752 (Thilawa) 246,323 (Ywama)	Based on manufacture's Catalog
Temperature of exhaust gas	ºC	559	103 (Thilawa) 559 (Ywama)	103 (Thilawa) 559 (Ywama)	Based on manufacture's Catalog
Wind Speed at 10m	m/s	3.1	3.1	3.1	Based on existing information
Height of the chimney (G.L.+)	m	20	20	20	Average based on existing information
NOx Emission concentration	ppm	260	260 (Thilawa) 260 (Ywama)	61 (Thilawa) 260 (Ywama)	Based on manufacture's Catalog (actual NOx emission concentrations are less than catalog's vales)

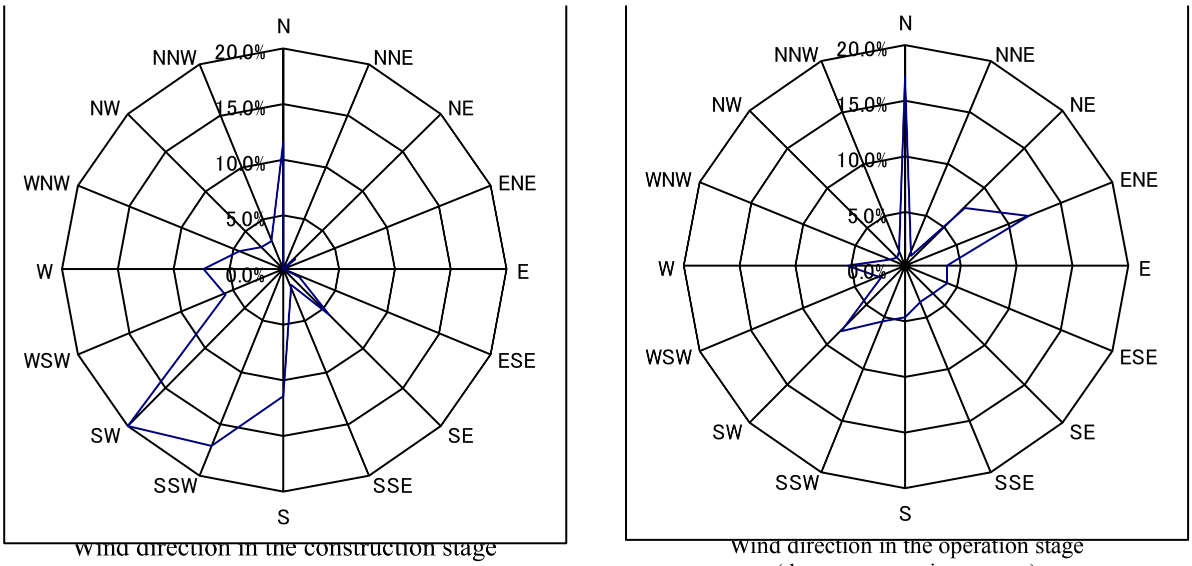
Source: JICA Study Team

2) Meteorological conditions

Meteorological conditions are basic information for the prediction of air quality. In this study, meteorological conditions are set based on the results of the field survey data in each season.

Wind direction and wind speed

Construction works will be conducted only during the dry season. That is the reason why wind conditions in the construction stage from the field survey data was set in the dry season. On the other hand, the gas turbines will be operated 24 hours a day, seven days a week. The wind conditions for prediction in the operation stage from all time data was set in the dry and rainy seasons. Figure 1 and Figure 2 show the wind direction and wind speed for each prediction stage.

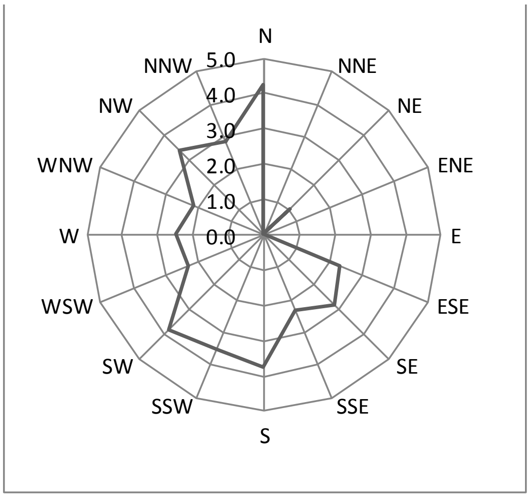


Wind direction in the construction stage (dry season)

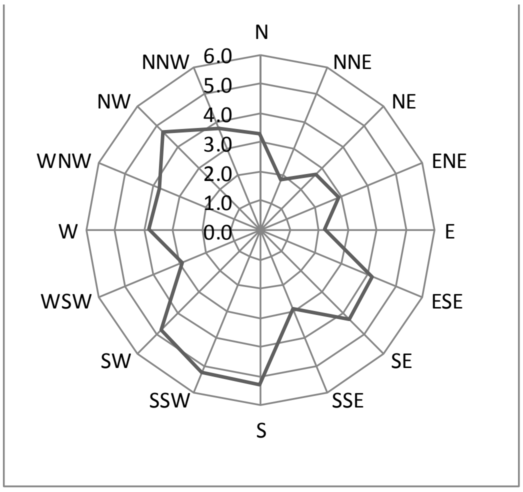
Wind direction in the operation stage (dry season + rainy season)

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

Figure 1: Wind Direction



(dry season)



(dry season + rainy season)

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

Figure 2: Average Wind Speed

<u>Atmospheric stability</u>

Atmospheric stability is an indicator used to describe the convective properties of an air mass. Table 2 and Table 3 show the classification of atmospheric stability.

Table 2: Atmospheric Stability and Corresponding Stability Condition

Atmospheric Stability	Stability Condition
A	Extremely unstable
B	Unstable
C	Slightly unstable
D	Neutral
E	Slightly stable
F	Stable
G	Extremely stable

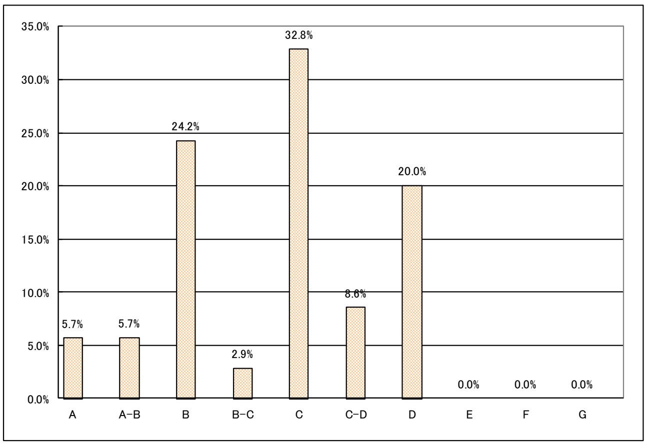
Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

Table 3: Classification of Atmospheric Stability

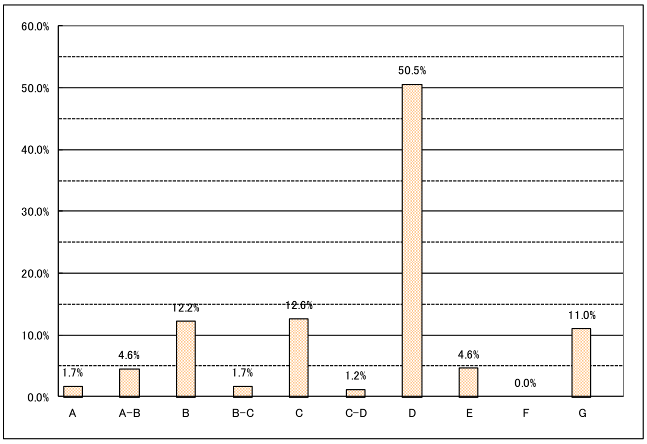
Wind Speed u (m/s)	Solar Radiation T (kW/m²)				Radiation Balance Q (kW/m²)		
	T≧0.60	0.60>T ≧0.30	0.30>T ≧0.15	0.15>T	Q≧-0.020	-0.020>Q ≧-0.040	-0.040≧Q
u＜2	A	A-B	B	D	D	G	G
2≦u＜3	A-B	B	C	D	D	E	F
3≦u＜4	B	B-C	C	D	D	D	E
4≦u＜6	C	C-D	D	D	D	D	D
6≦u	C	D	D	D	D	D	D

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

In this study, atmospheric stability was classified by each prediction condition same as what was done for wind conditions. Atmospheric stability for each prediction stage is shown in Figure 3.



Atmospheric stability in the construction stage (daytime, dry season)



Atmospheric stability in the operation stage (all time, dry season + rainy season)

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

Figure 3: Appearance of Atmospheric Stability Condition for Each Prediction Stage

3) Background concentrations

Background concentration is used to forecast future concentration of air quality. In this simulation study, the additional concentration from this Project was calculated. To forecast future ambient air quality, it is necessary to add ordinal background concentration to analytic solution. Background concentration was set from the results of the field survey. Background concentrations were set from the rainy season survey because the survey result in the dry season may have been affected from the power generator exhaust gas caused by electricity supply to the Environmental Perimeter Air Station (EPAS). Background concentrations are shown in Table 4.

Table 4: Background Concentration

Item	Unit	Background Concentration
NO_2	ppm	0.035

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

(2) Prediction model

The prediction model applied in this study is the Gaussian Plume Model, which is an analysis solution of diffusion equation and it is commonly used for air pollution forecasting.

The formula for concentration of air pollutant is based on the Gaussian Plume Equation and Puff Model as follows:

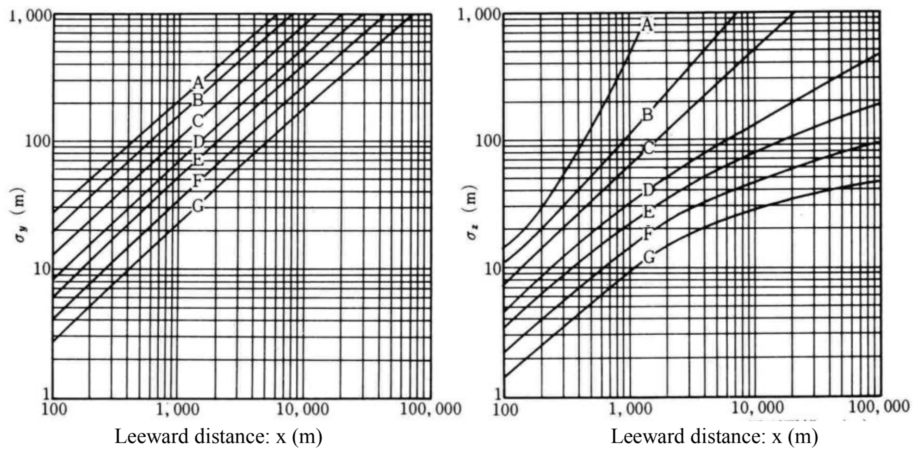
1) Gaussian Plume Model (In the case of wind velocity more than 1 m/s)

$$C=(x,y,z,T)$$

$$=\frac{Q}{2\pi U\sigma_y\sigma_z}\cdot\exp-\frac{y^2}{2\sigma_y^{\ 2}}\left[\exp\left\{-\frac{(z-H)^2}{2\sigma_z^{\ 2}}\right\}+\exp\left\{-\frac{(z+H)^2}{2\sigma_z^{\ 2}}\right\}\right]$$

Where

C (x, y, z) : Predicted concentration at coordinates of (x, y, z)
Q : Discharge per unit time (ml/s or mg/s)
U : Wind velocity (m/s)
H : Height of discharge (m)
σy, σz :Diffusion coefficient of horizontal/vertical width (m) (See Figure 4)
x : Coordinate of downwind axis (m)
y : Coordinate of horizontal axis(m)
z : Coordinate of vertical axis (m)



Horizontal Width (σy) **Vertical Width (σz)**

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

Figure 4: Diffusion Coefficient of Width

2) Weak Wind Puff Model (In the case of wind velocity more than 0.5 m/s and less than 0.9 m/s)

$$C=(x,y,z,T)$$

$$=\int_{t_o}^{T}\frac{Q}{(2\pi)^{3/2}\sigma_y(t)^2\,\sigma_z(t)}\cdot\exp\left\{-\frac{(x-ut)^2}{2\sigma_x(t)^2}-\frac{y^2}{2\sigma_y(t)^2}\right\}\left[\exp\left\{-\frac{(z-H)^2}{2\sigma_z(t)^2}\right\}+\exp\left\{-\frac{(z+H)^2}{2\sigma_z(t)^2}\right\}\right]dt$$

Where

C(x, y, z, T) : Predicted concentration at coordinates of (x, y, z) T: time

Q : Emission per unit time (ml/s or mg/s))
σy(t) : Diffusion coefficient of horizontal width at t-time later from discharge
(σx(t)＝σy(t)＝α • t)
σz(t) : Diffusion coefficient of vertical width at t-time later from discharge
(σz(t)＝γ • t)
H : Height of discharge (m)
t0 : Time of reach to initial diffusion width from discharge
u : Wind velocity (m/s)
α, γ : Parameters for diffusion width (See Table 5)

Table 5: Parameters for Diffusion Width (α, γ)

Atmospheric Stability	Wind Velocity ≤ 0.4 m/s		0.5 < Wind Velocity < 0.9 m/s	
	α	γ	α	γ
A	0.948	1.569	0.748	1.569
A-B	0.859	0.862	0.659	0.862
B	0.781	0.474	0.581	0.474
B－C	0.702	0.314	0.502	0.314
C	0.635	0.208	0.435	0.208
C－D	0.542	0.153	0.342	0.153
D	0.470	0.113	0.270	0.113
E	0.439	0.067	0.239	0.067
F	0.439	0.048	0.239	0.048
G	0.439	0.029	0.239	0.029

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

3) Puff Model (In the case of wind velocity under 0.5 m/s)

$$C(x,y,z,T)=\int_{t_o}^{T}\frac{Q}{(2\pi)^{3/2}\sigma_y(t)^2\,\sigma_z(t)}\cdot\exp\left\{-\frac{x^2+y^2}{2\sigma_y(t)^2}\right\}\left[\exp\left\{-\frac{(z-H)^2}{2\sigma_z(t)^2}\right\}+\exp\left\{-\frac{(z+H)^2}{2\sigma_z(t)^2}\right\}\right]dt$$

Where

C (x, y, z, T) : Predicted concentration at coordinates of (x, y, z) T: time
Q : discharge per unit time (ml/s or mg/s))
σy (t) : Diffusion coefficient of horizontal width at t-time later from discharge
(σx(t)＝σy(t)＝α･t)
σz(t) : Diffusion coefficient of vertical width at t-time later from discharge
(σz(t)＝γ･t)
H : Height of discharge (m)
t0 : Time of reach to initial diffusion width from discharge (s)

4) Polymerized concentration of air pollutant

The calculation for annual mean concentration of pollutant is conducted by using the following formula:

[Polymerization Formula]

C＝Σk Σj Σi C1(Di,Vj,ak)･f1(Di,Vj,ak)

+Σk Σj Σi C2(Di,Vj,ak)･f2(Di,Vj,ak)+ Σ kC3(ak)･f3(ak)

Where

C : Polymerized concentration
C1(Di,Vj,ak) : One hour concentration in the case of wind velocity more than 1 m/s
f1 (Di,Vj,ak) : Incidence of wind blowing (more than 1 m/s)
C2 (Di,Vj,ak) : One hour concentration in the case of weak wind blowing
f2 (Di,Vj,ak) : Incidence of wind blowing (more than 0.5 m/s and less than 0.9 m/s)
C3 (ak) : One hour concentration in the case of wind velocity under 0.5 m/s
f3 (ak) : Incidence of wind blowing (under 0.5 m/s)

(3) Estimation of wind velocity at the discharging height

Wind velocity for prediction is estimated from the low height wind data of the site survey. The following formula is used for estimation of wind velocity.

$U=U_0 \times (Z/Z_0)^{\alpha}$

Where

U : Estimated wind velocity at the height of Z (m)
U_0 : Surveyed wind velocity at the height of Z_0 (near ground level)
α : Power index

Generally, the power index “α” is a variable corresponding to atmospheric stability as shown in Table 6.

Table 6: Power Index for Estimation

Atmospheric Stability	A	B	C	D	E	F, G
α	0.1	0.15	0.20	0.25	0.25	0.30

Source: EIA Study for Project on Construction of Solid Waste Management Facilities in Thilawa SEZ Zone A

(4) Calculation of effective stack height

Under a windy condition, CONCAWE Stack Height Formulation is used for calculation of the effective rising height. Briggs Formulation is used under the weak wind condition and calm condition.

1) CONCAWE Stack Height Formulation (In the case of wind velocity more than 1 m/s)

$He=H_0+\Delta H$

$\Delta H=0.175\times Q_H^{1/2}\times u^{-3/4}$

Where

He : Effective stack height
H_0 : Height of chimney
ΔH : Rising height of exhaust gas
Q_H : Calorific value of exhaust gas
u : Wind velocity

2) Briggs Formula (In the case of wind velocity under 1 m/s)

$He=H_0+\Delta H$

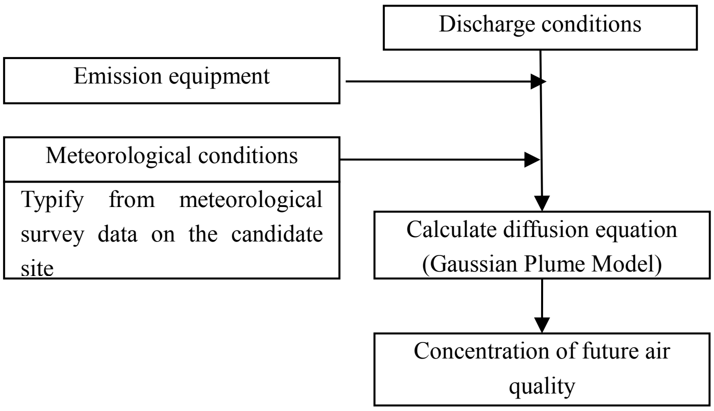
$\Delta H=1.4\times Q_H^{1/4}\times(d\theta/dz)u^{-3/8}$

Where

dθ/dz : Gradient of atmospheric temperature
day 0.003 ºC/m, night 0.01 ºC/m

(5) Prediction flow

The prediction flow is shown in Figure 5.



Source: JICA Study Team

Figure 5: Prediction Procedure Flow

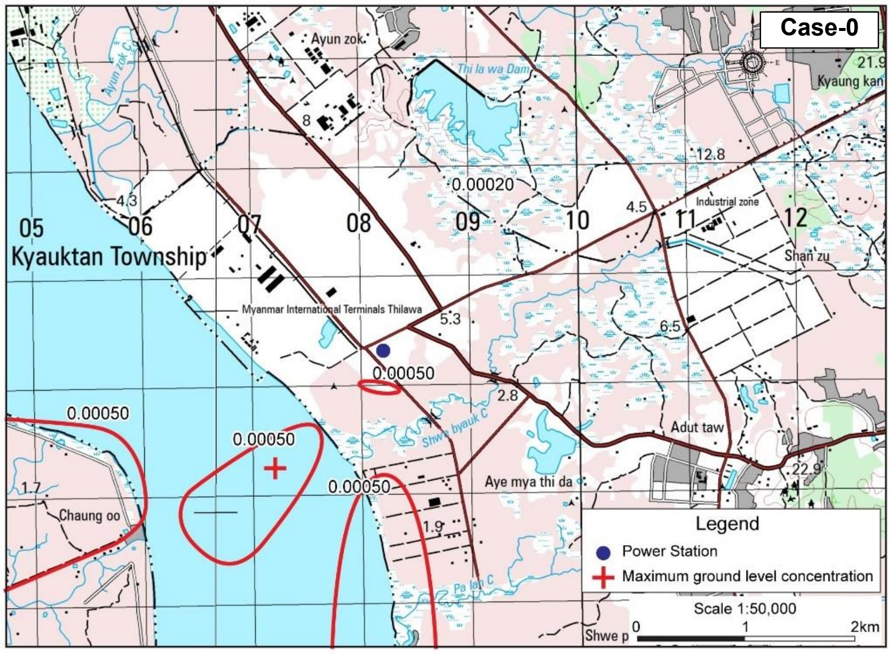
4) Results of Cumulative Impact Assessment

As the result of air quality simulation shown in Table 7 and Figure 6 to 8, maximum NO_2 concentrations at ground are is 0.03567 ppm at Case 0 (50 MW without water injection system), 0.03788 ppm at Case 1 (107 MW without water injection system), and 0.03788 ppm at Case 2 (107 MW with water injection system). Maximum ambient air quality at ground in all cases will comply with target ambient air quality level (0.06 ppm set as the target level in the existing draft EIA report same as Japanese standard) and contribution rate is small percentage. Thus, it was confirmed that cumulative impact on air pollution from the gas turbines will be limited.

Table7: Result of the Air Quality Simulation Model

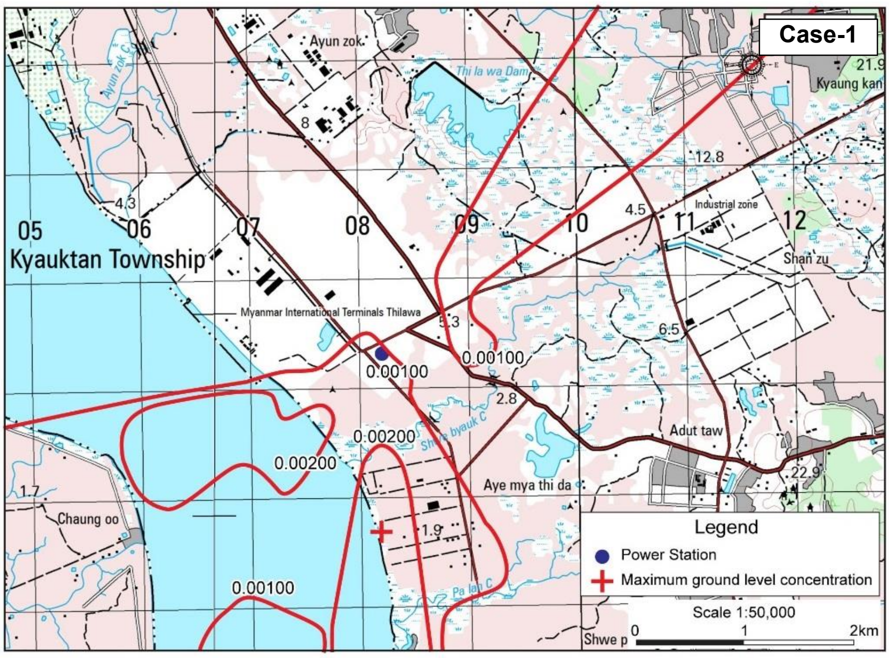
Case	Contribution of Emission Gas (NO2) by Simulation Model	Background Concentration (NO_2) in 2013	Maximum ambient air quality at ground (NO_2)	Target Ambient Air Quality Level (NO_2)	Contribution Rate
Case 0 (50 MW without water injection)	0.00067 ppm	0.035 ppm	0.03567 ppm	0.06 ppm (Same as Japanese Ambient Air Quality Level)	1.9%
Case 1 (107 MW without water injection)	0.00288 ppm		0.03788 ppm		7.6%
Case 2 (107 MW with water injection)	0.00065 ppm		0.03565 ppm		1.8%

Source: JICA Study Team



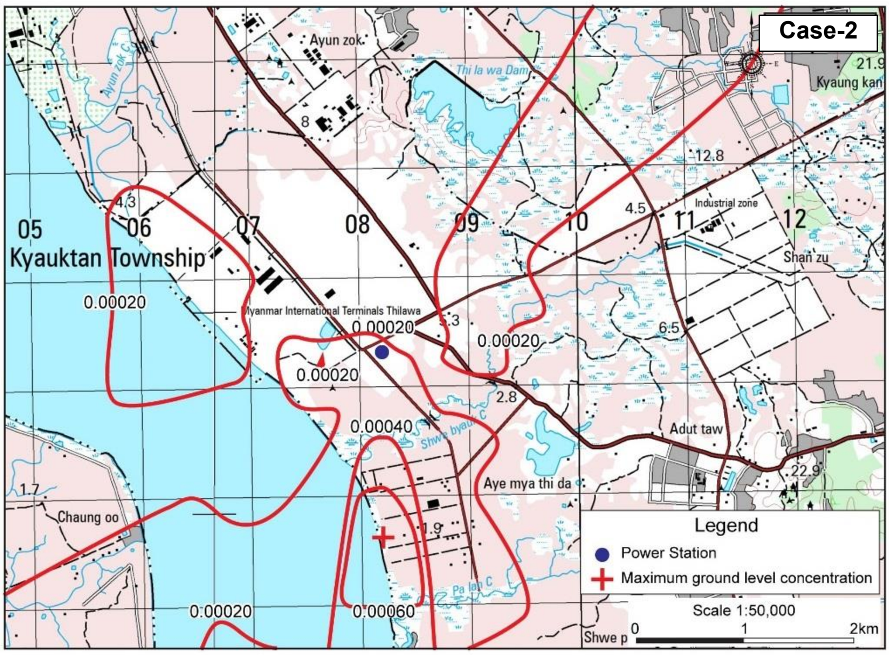
Source: JICA Study Team

Figure 6: NO_2 Concentration at Ground (Case 0: 50 MW without water injection)



Source: JICA Study Team

Figure 7: NO_2 Concentration at Ground
(Case 1: 107 MW without water injection)



Source: JICA Study Team

Figure 8: NO_2 Concentration at Ground (Case 2: 107 MW with water injection)